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U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 49, No. 12

DECEMBER, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

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ECONOMIES IN PRINTING.

Contributions intended for publication in the REVIEW must in all cases conform to the regulations of the Department of Agriculture with respect to effecting economies in the public printing. The following memorandum in regard to preparing manuscripts for publication has just been issued by the Department. It is reproduced below for the information of all concerned.

Authors will be expected to prepare their manuscripts, with the understanding that once the manuscript leaves the author's hands it is in final form and not subject to further changes of text in galley or page proof. With the adoption of this policy it will be necessary that authors consult workers on related subjects in other Bureaus before finally submitting their manuscript for publication, and all matters as to which there is difference of opinion must be settled in advance.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. An addressed franked slip may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.

SUPPLEMENT, No. 3.

(To face p. 637.)

FIG. 1.—Panoramic view of experimental area Wagon Wheel Gap, Colo. Rio Grande in foreground.

MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

VOL. 49, No. 12. DECEMBER, 1921. CLOSED FEB. 3, 1922
W. B. No. 761. ISSUED MAR. 10, 1922

STREAMFLOW AT WAGON WHEEL GAP, COLO.[1]

By CARLOS G. BATES and ALFRED J. HENRY.

Recently there has appeared under the title above given a preliminary report covering the first stage of the Wagon Wheel Gap Experiment. This experiment, it may be remembered, was planned to show quantitatively the effects of the removal of a forest cover on streamflow and erosion within the drainage basin whence it was removed. Briefly the plan may be outlined as follows: Select two contiguous watersheds similar as to topography and forest cover; observe carefully the meteorological conditions and the streamflow for a term of years under similar conditions of forest cover; then denude one of the watersheds of its timber and continue the measurements as before for such time as may be necessary to determine the effects of the forest destruction upon the time and amount of streamflow, the amount of the erosion, etc.

The outcome of these investigations will be awaited with great interest on the part of the public and the demand for copies of this report will doubtless be far in excess of the number printed. To anticipate this demand as far as practicable this rather full abstract is printed in the belief that it will satisfy the needs of many persons who have an academic interest in the project rather than a technical or professional one. Separates of this abstract can be obtained on application to the Chief of the Weather Bureau, Washington, D. C.

The plan above outlined has been carried out so far as the first stage of the experiment is concerned. The watersheds were selected by the Forest Service of the United States Department of Agriculture near the railroad station of Wagon Wheel Gap, Colo. The geographical coordinates of that station are N. lat. 37° 46′ W., long. 100° 53′. Elevation at the railway station, 8,437 feet above mean sea level.

Figure 1 shows the two watersheds as viewed from a point near the railway station of Wagon Wheel Gap.

On June 30, 1919, 8 years' continuous streamflow observations and nearly 9 years' continuous meteorological observations had been obtained. A consideration of this material showed that while the seasons themselves were more or less different, the one from the other, yet the rainfall-runoff relations on the average were approximately constant, or in cases of rather wide departure the deviations from the mean were easily explainable. It was therefore mutually agreed that one watershed (B) should be denuded. The program of denudation was completed in the autumn of 1920.

OBJECT OF THE PRESENT PAPER.

The object of this discussion is to give a clear idea of the nature of the experiment, the methods followed, the conditions observed to date, and the plan for analyzing the data obtained in the future so as best to bring out faithfully and clearly the effects upon streamflow and erosion which are produced by the denudation of one of the watersheds. Naturally, to be of tangible value, such effects must in some manner be shown quantitatively and statistically. It is especially to be hoped that the present discussion will bring out criticisms from irrigation engineers and others who are particularly interested in matters of water supply from mountainous sources, so that the final study of the results of the projects may succeed in presenting data of the most useful character.

According to the accepted boundary survey, the areas and dimensions of the two watersheds are as shown in Table I. (See also fig. 2.)

TABLE 1.

	A	B
Total area.....acres..	222.5	200.4
Extreme length.....feet..	7,300	4,600
Computed mean width...do....	1,328	1,898
Absolute elevations.....	9,373–11,355	9,245–10,952

The greater area of A as compared with B, as above indicated, is of no appreciable import. That which is of importance, in so far as it complicates the relationship of the discharges of the two streams for any short period, is the fact that watershed A is considerably longer and narrower than B, and includes a small area extending to an elevation about 400 feet higher than any part of B. As will be seen later through consideration of the discharge graphs, for the purpose of discharging any single supply of water (such as the fall of a single rain), watershed A might be compared to a narrow trough and watershed B to a fan-shaped collector. The former, on account of its relatively short slopes, is able to deliver the first bulk of a water supply in a relatively short time, and this quick delivery is the basis for a sharp and high flood crest in most cases; yet on account of its length, this area may continue to deliver water to the dams for a long time. By comparison, B delivers its water to the dam after a longer interval, but more largely in one mass, and completes its discharge sooner. Were we ever dealing solely with the water of a single storm or a single period of snow-melting, the relations above set forth might not be difficult to express by a concise formula. But, since the streamflow of any period we may choose to consider is necessarily built up from water contributions of many previous months, it becomes apparent that the watershed differences have introduced a maze of relationships we can not hope to unravel or to give expression to, except

[1] MO. WEATHER REV. SUPPL., No. 17, Bates, Carlos G., and Henry, Alfred J., pp. 55, figs. 41. Washington, D. C., 1922.

in approximate terms. The great difficulties of this situation, of course, could not be foreseen when the watersheds were chosen, nor is it at all certain they could have been avoided, as Nature has nowhere been so kind as to form two objects exactly alike.

Of some slight importance, as it affects snow-melting, is the fact that the main axis of watershed A is almost directly east-west, while that of B is more nearly northeast-southwest. In consequence, the north half or southerly exposure of A contains considerable areas which face squarely the mid-day sun, while on B the permeability, and retentiveness of the soil, but also because the present rock *in situ* has the greatest influence on underground water and on the possibility of complete measurement of the water discharged from the areas.

The first geological examination of these watersheds was made by Mr. E. S. Larsen, of the Geological Survey, in June, 1910, or while the first prospecting for the dams was under way. It is regretted that we can not quote here Mr. Larsen's original report, which was entirely reassuring, both as to the uniformity of the structure on the two areas and the probabilities of a structure at the

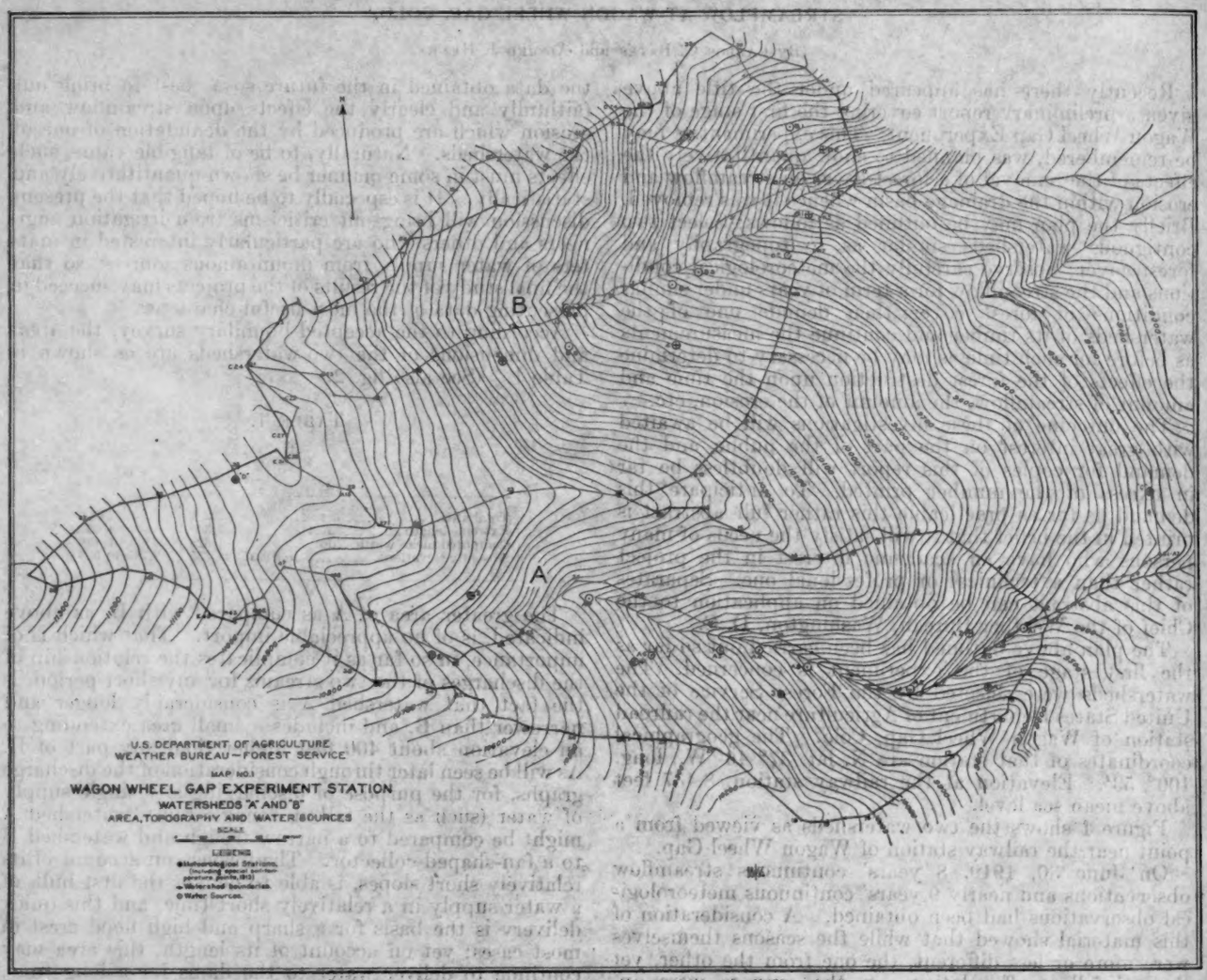

FIG. 2. Area, topography, and water sources.

corresponding position is very largely an east slope, except for a very small space at the lower end of the watershed. After a very careful survey of the several snow-scale areas, Keplinger (Apr. 1, 1913) computed the mean gradient of watershed A to be 25 per cent and of B 26 per cent; but the mean aspect of all the slopes on A is S. 85 E., while on B it is N. 68 E., a difference of 27 degrees.

Geological formation.—As has been stated, one of the first considerations was that the two areas studied should have similar geological origins, not only because the character of the rock defines the physical character, proposed dam sites which would insure a good foundation for the dams and the loss of none of the water which flows away from the areas.

Description of the forest.—The forest of the two watersheds involved in this study is one fairly typical of the middle zone of the central Rocky Mountains and is characterized by the predominance of Douglas fir.

On account of the character of the soil derived from a fine-grained igneous rock, western yellow pine is practically nonexistent in this locality and does not appear on the lower reaches of the watersheds at all, though in most of the region it would be expected on southerly exposures

at this elevation. Such exposures are occupied almost wholly by Douglas fir of good development, but forming open stands. There is everywhere a sprinkling of bristle-cone pine, which becomes more numerous at the tops of the slopes and wherever the amount of rock in or on the soil is very great.

The northerly exposures at low elevations are also characterized by fir stands, more dense, of course, than those of the warm slopes. There is everywhere a sprinkling of Engelmann spruce, and with increased elevation the proportion of this species increases, so that at the upper extremities of both watersheds the type is almost pure spruce.

A large part of watershed B, and only slightly less acreage in A, was burned over, as nearly as can be determined, about 1885. While the fire may or may not have run through the stands on the southerly exposures, their open character prevented serious damage, and such areas may be considered to be now in an essentially normal state as regards cover. Much greater damage was done to the north-slope fir stands, on practically all such acreage of watershed B, and in strips on the lower portion of A, while the prime spruce forest at the upper ends of A and B was almost completely destroyed, and a considerable part of this area is not now covered even by aspen, except in occasional clumps.

LOCATION OF OBSERVING STATIONS.

In the beginning it was thought advisable to establish six primary meteorological stations. One is near the office and living quarters and is called the C station; there are two on each of the watersheds, and the last is on the extreme upper portion of A, to represent the higher altitudes of both watersheds, known as the D station.

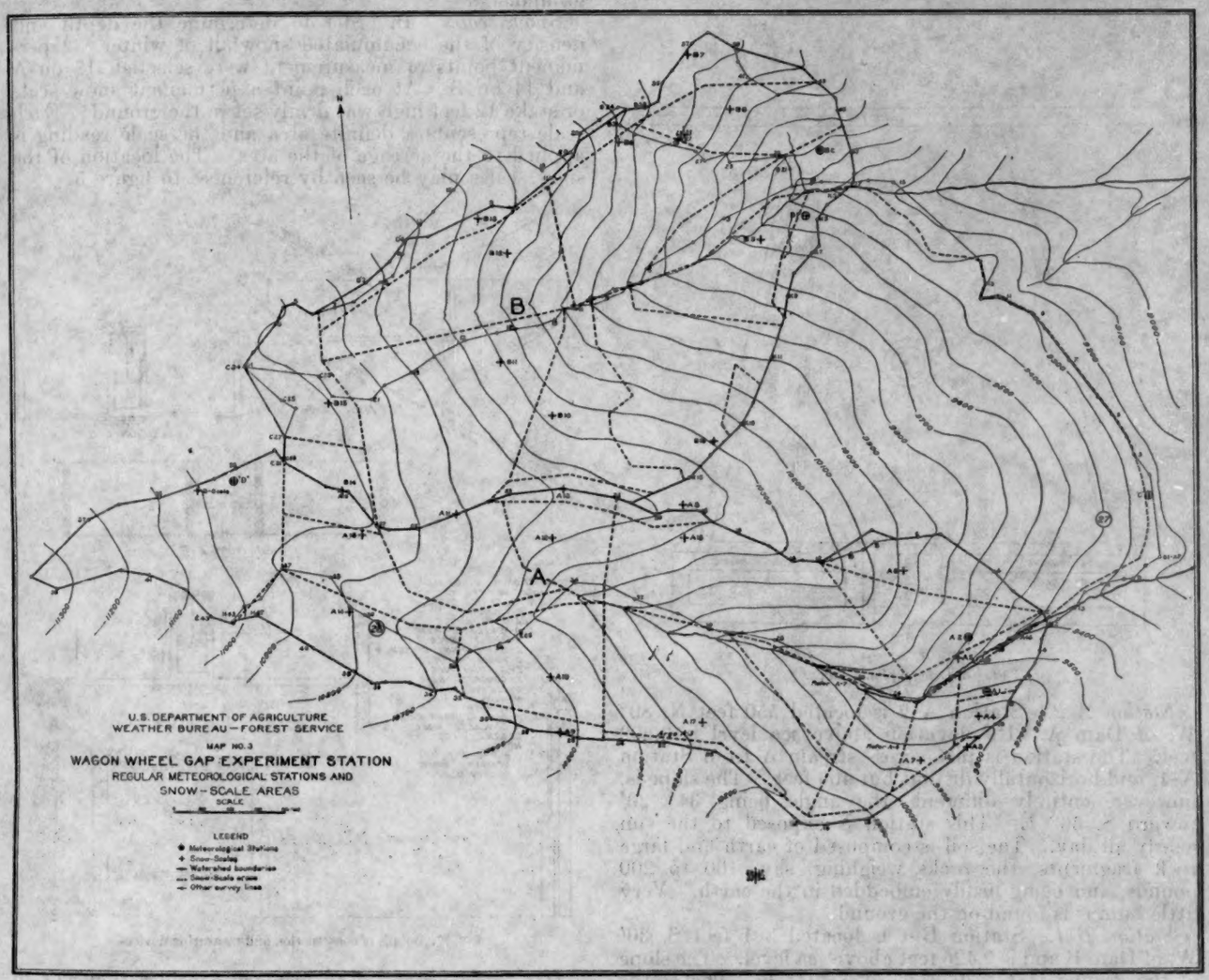

FIG. 5. Meteorological stations, snow scale areas.

The primary stations on both watersheds are situated near the lower boundaries, one on the north slope and the other directly across the ravine in which the stream flows, on the opposite slope. North-slope stations are known as A–1 and B–1, south-slope as A–2 and B–2. The two pairs of watershed stations are the most important, and for this reason the location of these stations was selected with great care, the object being to secure as nearly identical conditions of topography and timber cover as possible. A–1 occupies about the same topographical position in Watershed A as B–1 in Watershed B, and A–2 the same as B–2.

The general topography of the watersheds and the location of primary and secondary stations are shown in figure 5.

Station A–1.—Station A–1 is 700 feet S. 40° W. of Dam A, and 9,601 feet above sea level. The station is on a steep slope, angle 31° 20′, azimuth N. 24° W. Directly west of the thermometer shelter is a large open rock slide. While the surface of the ground at the station has a shallow covering of moss and fir needles, there is very little soil in the ordinary meaning of that term.

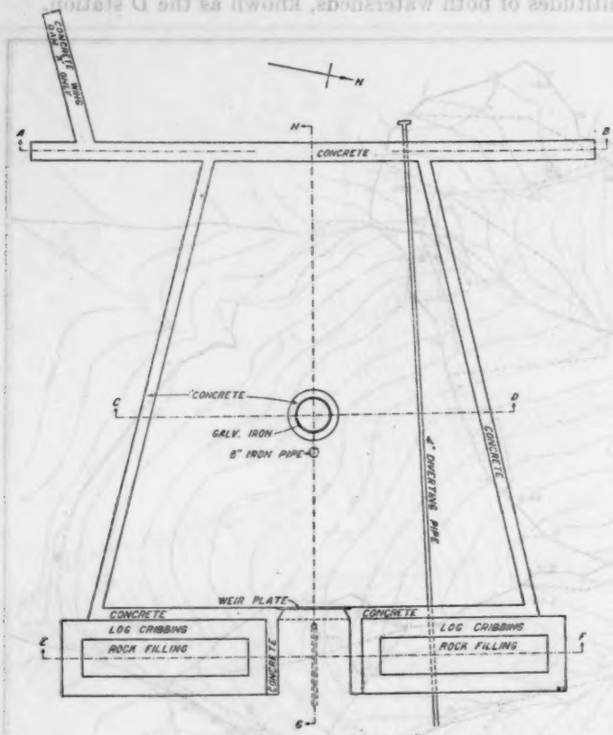

FIG. 6. General plan of dams.

Station A–2.—Station A–2 is located 550 feet N. 80° W. of Dam A. Its elevation above sea level is 9,609 feet. The station is just across stream A from Station A–1, and horizontally distant but 406 feet. The slope is, however, entirely different, the angle being 34° 20′ toward S. 56° E. This station is exposed to the sun nearly all day. The soil is composed of earth and large rock fragments, the rocks weighing, say, 100 to 200 pounds, and being firmly embedded in the earth. Very little humus is found on the ground.

Station B–1.—Station B–1 is located 381 feet S. 30′ W. of Dam B and is 9,426 feet above sea level. The slope of the ground is 37° 30′ toward N. 24° E. The soil is mostly a sandy loam, with broken rock interspersed and with a good cover of fir needles. The station receives but little sunshine in winter.

Station B–2 is situated directly across the ravine, as may be seen from the map, fig. 5. It stands in the same relation to B–1 as does A–2 to A–1.

Station D.—Station D is located near the top of the mountain, elevation 10,949 feet above sea level. This station is in the burned region, and hence the only timber consists of dead trees, standing and fallen. The ground in the vicinity of the station is practically level. The station is exposed to winds from all directions except the west, where it is slightly protected by rising ground.

Station C.—The C station was from the start equipped with a rather complete set of meteorological instruments as follows: Two standard barometers, a barograph, a triple register recording wind direction, velocity, sunshine, and rainfall. A standard Weather Bureau instrument shelter on galvanized-iron supports was installed on a grass-covered east slope, 400 feet north of the office building, and the rain-gage was placed 300 feet farther north in a stand of young aspen. The floor of the instrument shelter is 11.3 feet above ground, the wind vane is 16.9 feet, and the anemometer is 15.6 feet above ground.

Snow scales.—In order to determine the depth and density of the accumulated snowfall of winter, 32 permanent points of measurement were selected, 18 on A and 14 on B. At each point a permanent snow scale or stake 12 feet high was firmly set in the ground. Each scale represents a definite area and the scale reading is applied to the acreage of the area. The location of the snow scales may be seen by references to figure 5.

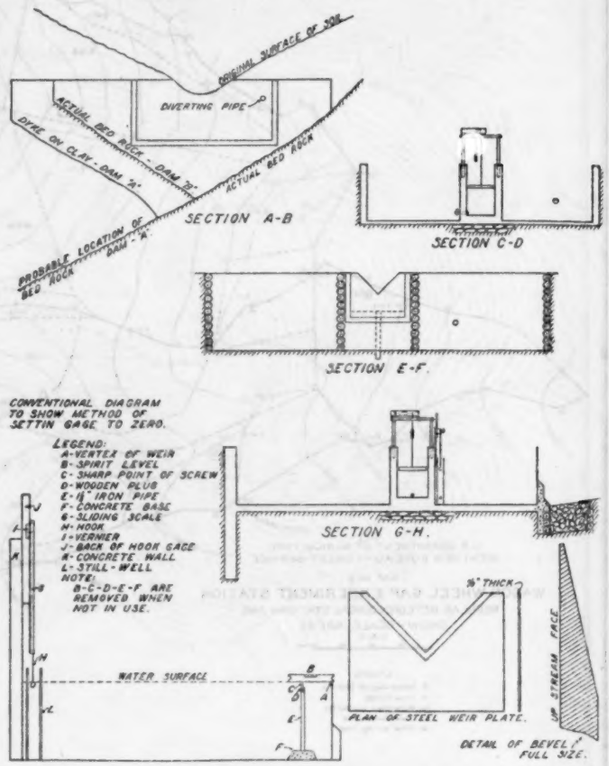

FIG. 7. Details of construction and measuring devices.

Dam construction.—The primary consideration was to construct a wall across either stream channel by means of which both the surface and subflow of the channel could be collected for measurement. This was accomplished, after digging the cross trench down to a solid foundation, by pouring a solid concrete wall to a height at least a foot greater than that of the original stream channel, except at the center of the channel, where a notch was left through which the stream might flow. The thickness of this wall was 8 inches, except at the bottom, where the concrete was allowed to spread out the full width of the trench. The general plan of the dams is shown in figure 6, and additional information is afforded by figure 7 and half-tone figures 8, 9, 10, 11, and 12.

(To face p. 640.)

FIG. 3.—Conditions in a young Coniferous stand, typical of much of the upper portion of A.

FIG. 4.—Rather large Douglas fir surrounding thermometer shelter at station A-2.

FIG. 8.—Completed basin at Dam A—from upstream end—column in center still-well, later enlarged for 20-inch float.

FIG. 9.—Completed basin at Dam A—downstream end—with rectangular weirs.

FIG. 10.—Basin at Dam A covered with shelter house for register.

FIG. 11.—Basin at Dam B just ready to cover.

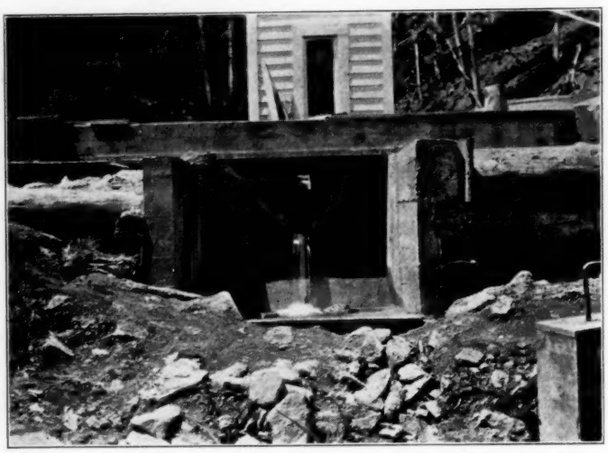

FIG. 12—Triangular weir—Dam B—which replaced rectangular weir of 1911.

THE PROGRAM OF OBSERVATIONS.

The program of meteorological and stream-flow observations as originally adopted was not materially changed during the first stage of the experiment. It involves daily observations, at 9 a. m., at Stations A–1, A–2, B–1, B–2, and C.

In the beginning the north-slope stations of the two watersheds were given the more complete instrumental equipment as follows: Maximum, minimum, dry and wet thermometers, a thermograph, a hygrograph, an anemometer, a standard 8-inch rain gage, a 5-foot snow bin, and a 12-foot snow scale, the latter set permanently into the ground. Later in the experiment a shielded snow gage of the Marvin pattern was added at all of the meteorological stations. Thermometers for determining the soil temperature at depths of 12 and 48 inches were also added on north slopes in 1912. Weekly determinations of soil moisture at all watershed stations were made during the summer months of 1914 to 1919, both inclusive.

The equipment of the south-slope stations in the beginning was limited to maximum and minimum thermometers, a rain gage, and a snow scale. On May 31, 1913, the thermometric readings were discontinued and a little later soil temperatures at 18 and 48 inches were begun. Precipitation was continuously recorded at south slope stations throughout the experiment.

Finally, measurements of depth of snow on the ground *daily* were made at all primary watershed stations except D. Beginning with December of each year, a bimonthly measurement of the depth and density was made at each snow-scale on the watershed until near the beginning of the snow-melting season in the spring, when the measurements were made at three-day intervals in 1912 and 1913. Beginning with March, 1914, and continuing to date, the observations have been at five-day intervals during that period.

At the D station, by reason of its remoteness from the camp, the sheets of the automatic instruments were changed at 6-day intervals and eye readings for check purposes were made on the dates when the sheets were changed. The daily record of wind velocity and of rainfall in the summer were automatically registered in the office at the C station by electrical transmission line.

Stream-flow measurements.—The height of the water in the basin above the V-notch in the weirs was automatically recorded by a Friez water-stage recorder and the instrumental record was checked by the daily reading of a hook gage.

In July, 1911, the rectangular weirs were torn out and triangular weirs installed. The advantages of triangular weirs may be stated as follows: Perfect aeration of nappe; automatic accommodation to all stages, with particular advantage in the case of extremely low stage; an increased amplitude of oscillation of the water surface in the basin at low stage, with consequent increase in the accuracy of the measurements; the use of but one function, height, in the computations; and the elimination of the leading channels from the structural work. These leading channels are difficult to construct with uniform sides, while without them a difficult and doubtful correction for end contraction must be introduced. The weirs are simply steel plates 3 feet by 4 feet and 0.5 inch thick, out of which right-angled notches have been cut. The vertical depth of each notch is 1.5 feet, which gives a maximum capacity of 7 second-feet—seven times greater than the crest of the flood of October, 1911. The faces of the weirs are beveled off for a distance of 2 inches on the downstream side, with a crest width of one-sixteenth inch. The flow of water under gravity over a triangular weir of this form is given by the U. S. Geological Survey as 2.64 times the five-halves power of the head, the flow being expressed in cubic feet per second, and the head being the vertical height in feet of the still water in the pond above the vortex of the weir notch. The above formula is the same as derived by Prof. James Thompson, of Belfast, in the experiment with a trinagular weir of a piece of thin sheet iron.

For the purpose of measuring the height of the water in the basin above the weir notch, a Boyden hook gage, an instrument familiar to engineers, is used. The essential principle of the instrument is that the setting is effected by causing the point of a hook to approach the water surface from the *under* side. The method is so accurate that different observers never vary more than 0.001 foot from the same reading. The Boyden gage is secured to a concrete wall by means of bolts set in the concrete. For the purpose of stilling any waves that may be present, a piece of iron pipe, 6 inches in diameter, the top projecting about 6 inches above the water, is set under the hook gage. The pipe rests unevenly on the concrete bottom of the basin, and to provide further for the free access of water, a half-inch hole was drilled through the side of the pipe 6 inches from the lower end. For the purpose of setting the zero of the hook gage to the level of the weir notch, a special arrangement was devised. A section of iron pipe was embedded in a concrete base weighing some 10 pounds. Into the top of the pipe a wooden plug was driven. A screw hook was then straightened out and one end sharpened to a point. The screw hook was then screwed into the wooden block so that the length of the base pipe and hook was approximately the depth of the water in the basin about a foot back of the weir. The entire apparatus was then set into the basin just back of the weir. By means of a spirit level, one end of which is filed to fit into the weir notch, the point of the screw hook may be finally adjusted to the level of the weir notch. The water in the basin is then adjusted so that the screw hook just pierces the surface. The hook gage may then be set to its zero. The method is simple and accurate, and frequent examinations of the accuracy of the zero may be made without difficulty. A diagram showing the method is appended (fig. 7).

Discharge coefficients.—To obtain the high degree of accuracy required in the stream-flow investigation, it was thought best actually to determine the discharge coefficients rather than to accept the published values. This was particularly necessary because the weirs differ slightly from the Thompson weir in that they had to be made one-half inch thick to provide the necessary strength, while the Thompson weirs were of thin sheet iron. Furthermore, every weir must of necessity be subject to its own departures in construction from a theoretically perfect cutting of the angle, crest width, and level. Also, in placing the weir in position, the concrete may set unevenly, thus throwing the weir slightly out of plumb. For each dam, three tanks made of 16-gage galvanized iron, with iron hoop at the top rim, each tank 4 feet in diameter and 4 feet in depth, were mounted on a platform built far enough below the dam to give the required fall. Over the middle of the platform a galvanized-iron funnel, top 24-inch diameter, tube 6-inch diameter, was suspended in a gimbal or universal joint, so that the lower end of the funnel hung just above the tops of the tanks. The overflow from the weir is conveyed into this funnel through a V-shaped trough, lined with galvanized iron. The method of

suspension of the funnel permits the water to be directed into either of the three tanks or into a wooden waste pipe the change being effected in a fraction of a second. The areas of the tanks were determined by taking the circumferences at four heights in each tank with a steel tape, then computing the mean area for that portion of the tank used, allowance being made for the thickness of the iron. To eliminate the error due to irregularity of bottom the tanks were first filled to a depth of about 2 inches and measurements of this height and of the height after the tank was filled were made by means of a hook gage, which was made by transcribing the graduations from a surveyor's rod. The time of beginning and ending a test was determined by use of an ordinary watch. Tests were made by two men, one man making continuous readings of the hook gage in the basin while the second man filled the tanks. Practically all of the tests were made at times of very little fluctuation in the head, and the mean of all hook-gage readings was used as the head. The detailed measurements and computations are too numerous to reproduce. Each individual entry represents a measurement of from 40 to 130 cubic feet of water, most tests having been made with the larger amounts.

THE CLIMATE OF THE WAGON WHEEL GAP AREA.

The geographic location of the Wagon Wheel Gap area, remote from both oceans and in the midst of a rugged mountain area, imposes upon it a climate which partakes of the characteristics both of mountain and continental climates.

Moreover, it lies to the southward of the general path of cyclonic storms, a fact which has an important bearing upon its climate.

AIR TEMPERATURE.[1]

The discussion of temperature is based on daily systematic observations of standard thermometers exposed in the regulation thermometer shelter at the north-slope stations of both watersheds for a period of eight years, 1911 to 1918, inclusive. Daily thermometric observations are also available for the south-slope stations on both watersheds from November, 1910, to May, 1913, a period of 31 months. Thermographs were maintained at north-slope stations and also at the D station for the entire eight-year period and at the G station for the four years, 1914 to 1917. The monthly means as deduced from hourly readings of the thermographs, checked by daily comparisons with the mercurial thermometers in the case of A and B, and weekly comparisons in the case of the D and G stations, are given in Table 1.

TABLE 2.—*Monthly mean temperature, north-slope stations of watersheds A and B.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
A.....	15.6	17.7	24.3	32.4	41.3	51.1	53.6	51.8	45.5	35.9	24.8	14.7
B.....	14.9	17.3	24.0	32.5	41.5	51.2	53.8	51.8	45.3	35.8	24.3	13.9
D.....	15.6	17.0	21.2	27.7	36.3	47.5	50.2	49.0	43.0	33.6	24.7	15.1

Considering the north-slope stations as representative of the watersheds, it is at once apparent that the mean temperature of the two watersheds is practically the same. The differences range from 0.8° in December to 0° in August. A is uniformly higher than B, except in the months April to July, inclusive, when it is a small fraction of a degree cooler on the average than B.

The D station, at an elevation of 1,355 feet higher than A–1, and 1,530 feet higher than B–1, has practically the same winter mean temperature as the lower stations, a spring temperature 4° lower, summer about 3° lower, and autumn 1.5° lower. The winter minimum temperatures of the D station are considerably higher than those of the lower levels; hence the equality in the winter means.

South slopes.—The south slope of each watershed is somewhat warmer than the north slope, but the excess in the monthly means is generally less than a whole degree, except that for the cold months, November to March, it may amount to as much as 2° or 3°. The excess in monthly means, south over north slope, is as follows:

	November.	December.	January.	February.	March.
A.....	2.1	1.8	1.8	1.6	0.6
B.....	2.5	3.0	2.7	2.6	1.8

This comparison is based upon monthly means that have been derived from the daily extremes instead of the 24-hourly readings as in Table 6. A series of corrections to reduce the means derived from the daily extremes to the true daily means shows that for watershed A the mean temperature, maximum and minimum, divided by 2, gives results that are in excess of the true daily means by amounts varying from 0 in February to 2.1° in August. In general, the corrections for the summer months in both watersheds are the greatest. In the B watersheds small positive and negative corrections offset each other in the mean, with the result that in three months of the year the correction is zero. In the A watershed positive corrections were rarely found in the individual months and not at all in the final means. Further analysis of the excess in monthly mean temperature as above shows that this excess is due to higher maxima on the south slopes of the respective watersheds.

	Excess of maxima on south over north slope (31 months' observations), means for—				
	November.	December.	January.	February.	March.
Watershed A.....	3.6	3.3	3.4	2.7	0.8
Watershed B.....	5.3	4.9	5.0	4.4	3.3

The mean minima for the identical periods and slopes are slightly higher for the south than for the north slopes, although the greatest excess for any month does not equal 1°. If we go still further and make an intercomparison between corresponding slopes of the two watersheds we find that the mean temperature, regardless of how obtained, is substantially the same. As illustrating this feature, the monthly means of the daily extremes for the eight full years at the north-slope stations is presented in Table 2.

[1] Degrees Fahrenheit and English units are used throughout this discussion.

TABLE 3.—*Monthly means of the daily maxima and daily minima.*

WATERSHED A.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Max.....	25.3	28.4	36.4	44.6	54.3	66.6	68.6	67.0	59.7	47.7	36.1	24.2	46.6
Min.....	6.2	7.7	13.7	22.0	29.7	37.5	42.8	40.8	34.6	26.1	15.2	5.8	23.5

WATERSHED B.

Max.....	24.4	27.8	34.9	43.1	53.3	65.6	67.6	65.6	57.9	47.1	35.3	23.3	45.5
Min.....	5.6	7.2	13.5	21.8	29.3	36.9	42.3	40.3	34.1	26.0	14.7	5.1	23.1

D (UPPER PART WATERSHED A).

Max.....	24.9	27.0	31.7	37.3	45.9	58.0	60.7	60.0	53.7	43.8	35.4	24.6	41.9
Min.....	7.5	8.9	12.3	18.9	27.1	37.8	41.8	40.3	34.4	25.1	16.2	7.4	23.1

SOIL TEMPERATURE.

The superficial soil layers receive and absorb incoming solar energy by day and lose heat as outgoing radiation by night. Whenever, therefore, the incoming radiation is in excess of the outgoing, the temperature of the soil rises and in due season reaches an annual maximum, thence receding to the annual minimum in midwinter. As in the case of air temperature, there are also short periods of temporary rises and falls in the temperature of the soil, as well as the more gradual seasonal progression. The magnitude of the accidental changes is largely a matter of the depth below the surface at which measurements are made. In this discussion we are concerned almost wholly with the seasonal changes at a depth of 12 inches, although observations of soil temperatures at a depth of 48 inches are also available. Between 5 and 6 years observations are available for both watersheds, and the D station representing the extreme upper portion of watershed A. The detailed weekly means for both slopes of the two watersheds are given in Table 4.

TABLE 4.—*Weekly mean soil temperature, 12 inches below surface.*

Date.	North slopes, 12 inches.		South slopes, 12 inches.		Date.	North slopes, 12 inches.		South slopes, 12 inches.	
	A.	B.	A.	B.		A.	B.	A.	B.
Jan. 7	19.9	24.0	29.8	26.6	July 1	41.6	46.1	54.7	56.3
14	19.1	23.5	28.6	25.9	8	43.3	47.1	54.8	56.3
21	19.2	23.3	28.4	25.9	16	45.1	48.0	55.7	55.6
28	18.7	23.1	27.7	25.0	23	47.2	48.7	54.2	55.7
Feb. 4	19.1	22.9	28.0	25.4	30	47.9	48.7	53.6	54.8
11	18.7	23.4	27.9	25.8	Aug. 6	48.1	49.3	53.7	55.0
18	18.7	23.5	28.3	26.6	13	47.6	49.3	53.3	54.5
25	19.4	23.7	28.7	27.1	20	47.4	48.3	52.0	53.2
Mar. 4	20.3	24.2	28.6	28.5	27	46.5	48.0	51.8	53.1
11	20.4	24.3	29.1	28.0	Sept. 3	45.3	47.4	51.1	52.4
18	21.1	24.8	31.5	28.9	10	44.4	46.2	50.8	51.5
25	21.3	25.1	31.2	30.7	17	42.3	44.2	48.8	49.8
Apr. 1	22.1	25.8	32.0	32.2	24	38.8	42.4	48.7	49.3
8	23.4	26.8	32.5	33.5	Oct. 1	36.4	40.6	46.7	46.6
15	24.8	28.1	33.4	34.6	8	35.4	39.7	45.8	45.1
22	26.9	29.4	33.8	35.1	15	34.0	37.6	44.1	42.4
29	29.7	30.2	35.4	37.0	22	32.8	35.8	42.5	41.4
May 6	31.6	31.2	36.4	37.5	29	32.3	34.5	41.7	40.0
13	31.8	32.7	38.8	39.7	Nov. 5	31.6	33.3	40.9	39.4
20	32.1	34.2	40.6	42.4	12	31.1	32.7	39.8	37.5
27	32.1	36.2	42.2	43.8	19	29.1	31.0	36.4	34.3
June 3	32.2	38.0	43.7	45.2	26	25.8	29.4	36.4	33.6
10	34.4	39.4	45.0	46.9	Dec. 3	23.2	28.0	35.3	31.9
17	37.2	41.9	49.9	51.8	10	22.6	26.9	33.9	30.1
24	39.5	44.1	52.6	53.8	17	21.3	26.6	32.0	27.7
					24	20.6	24.9	30.3	27.9
					31	20.0	24.2	29.9	26.7

PRECIPITATION.

The precipitation is measured daily at five points within walking distance of the headquarters station, viz, (1) at station C (headquarters), which may be considered as representative of the southern portion of both watersheds, (2) in watershed A and B, respectively, at the slope stations A–1 and A–2, B–1 and B–2, and finally at the D station. Recording rain gages of the tipping-bucket type are in operation during the warm season at stations C and D, and the records from these stations are used to apportion the hourly amounts in both watersheds throughout the 24 hours. The watershed precipitation, midnight to midnight, is determined by taking the larger of the two quantities recorded at the two rainfall stations in each watershed, adding to that quantity the amount of the precipitation at D and dividing the sum by 2.

The watershed precipitation as thus determined is given in table 9. On the average of eight years, watershed A has a mean annual precipitation of 21.02 inches and watershed B of 21.09 inches, or practically the same. The greatest difference in any one year was 1.03 inches, in 1912–13, B having the greater amount.

Colorado being remote from any large body of water and somewhat south of the average path of cyclones, does not at any season receive a generous amount of precipitation. The greatest average for the State, 20 to 25 inches, occurs on the western slope of the Rocky Mountains at altitudes above mean sea level of 10,000 feet and over. While the extreme upper part of both watersheds has an altitude somewhat above 10,000 feet, the situation of the area, with respect to the westerly winds, is not favorable to heavy precipitation, since westerly to northerly winds are descending winds and consequently dry. The precipitation is very nearly equally divided between rain and snow, with the former about 4 per cent greater than the latter; thus, rain 52 per cent and snow 48 per cent.

There is a well-marked rainy season in July and August, at least 55 per cent of the rain falling in those months. Precipitation as rain may occur as early as April and as late as October, although in late spring and early autumn, when beginning as rain, it is quite apt to change to snow before it ends. Snow in considerable amounts may fall in the latter part of September, but the real beginning of the snow season may be fixed as the last week in October. The first snowfall usually disappears by melting and evaporation, and it is not until the temperature during the afternoon hours does not rise above freezing that the snow cover may be said to be permanent for the winter.

Rainfalls of great intensity rarely occur at Wagon Wheel Gap. During the eight years considered, but a single heavy 24-hour rain occurred, viz, on October 5–6, 1911.

Greatest amount of precipitation in 24 hours.—The greatest amount of precipitation that occurred as rain or snow for each month from the beginning of observations to June 30, 1919, is given in Table 5. The data are for the C (headquarters) station. The maximum amounts for the months May to October occurred as rain, for the remaining months as snow. This table clearly shows that heavy rains as much as 2 inches in 24 hours are rare.

TABLE 5.—*Greatest amount of precipitation in 24 hours (inches and hundredths).*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1910.....											0.40	0.20
1911.....	0.36	0.63	0.47	0.18	0.31	0.44	0.71	1.27	0.56	2.60	0.36	.67
1912.....	.20	.23	.46	.42	.13	.53	.77	.63	.14	.69	.37	.35
1913.....	.32	.34	.43	.27	.21	.75	.61	.77	.98	.27	.45	.54
1914.....	.83	.40	.30	.22	.60	.67	1.22	.48	.72	.58	.01	.45
1915.....	.38	.68	.11	.60	.37	.29	1.00	.73	.88	.25	.92	.78
1916.....	.63	.12	.42	.37	.24	.11	1.11	.89	.37	1.03	.16	.24
1917.....	.75	.26	.24	.98	.43	.13	.69	.39	.25	.09	.55	.18
1918.....	.30	.47	.83	.47	.09	.20	.82	.89	1.04	.36	.85	.58
1919.....	.04	.29	.69	.38	.40	.56						

Intensity of precipitation.—To present statistics of intensity of precipitation in some detail, the 24-hour precipitation (rain or snow) has been classed according to the scale shown in Table 6. Since, however, the runoff from snow appears at the end of the cold season and is not immediately effective in producing increased streamflow, the *rain only* has been classified in groups according to intensity of the 24-hour amounts. It is considered that rains of 0.10 inch and less in the summer, as a rule, serve merely to replenish losses due to transpiration and evaporation and do not directly effect streamflow. Rains greater than 0.10 inch may be considered effective in producing a slight increase in streamflow, depending, of course, so far as the lower limit of the scale is concerned, upon conditions of soil moisture and other factors. With a saturated soil a precipitation so small as 0.01 inch, will produce a measurable response in streamflow.

The result of this second classification of rains gives the following very interesting results (in hundredths of an inch):

	Average intensity of rains.				
	June.	July.	August.	September.	October.
A	0.26	0.33	0.30	0.32	0.40
B	.31	.33	.30	.35	.46

This tabulation shows conclusively that the intensity of the rains is practically the same for each month of the season and substantially the same on both watersheds, with a tendency to be greater on B, at times, than on A.

TABLE 6.—*Intensity of rainfall A (days with total precipitation).*

	Days with—						Total effective rains (days).	Total rainy days, 0.02 inch or more.
	(1) T. to 0.01 inch.	(2) 0.02 to 0.10 inch.	0.11 to 0.30 inch.	0.31 to 0.50 inch.	0.51 to 1 inch.	1 inch and over.		
1912	42	59	43	13	3	0	59	118
1913	67	61	36	10	11	0	57	118
1914	58	67	36	11	9	0	56	123
1915	50	45	32	13	8	2	55	100
1916	37	63	32	17	9	1	59	122
1917	66	38	26	14	5	1	46	104
1918	77	62	43	12	8	2	65	127

The rainfall intensity has been independently computed by dividing the average monthly precipitation by the average number of rainy days, classing as a rainy day all days with 0.02 inch of precipitation or more.

The results are shown graphically in figure 13, and are explained as follows: The average monthly precipitation (adjusted) is shown by the rectangular figures opposite the respective months. The heavy line in the center of the rectangle represents the average number of rainy days and the shaded portion of the rectangle at the bottom gives the intensity of the precipitation as above indicated. The intensity by this method is somewhat less than when only the so-called effective rains are considered.

Thunderstorms.—Much of the summer rain comes in the form of afternoon thundershowers in July and August. Thundershowers may occur, however, as early as April, before the snow cover has disappeared from north slopes. The amount of rain which falls in these early thundershowers rarely exceeds half an inch, the greater part of which is absorbed by the snow cover. Since the weather associated with April and May thunderstorms generally turns cooler and the precipitation which begins as rain turns to snow, the run-off never assumes flood proportions. The thunderstorm season is from the last half of April to the middle of October, and the months of greatest frequency July and August. The average number per season is 70.

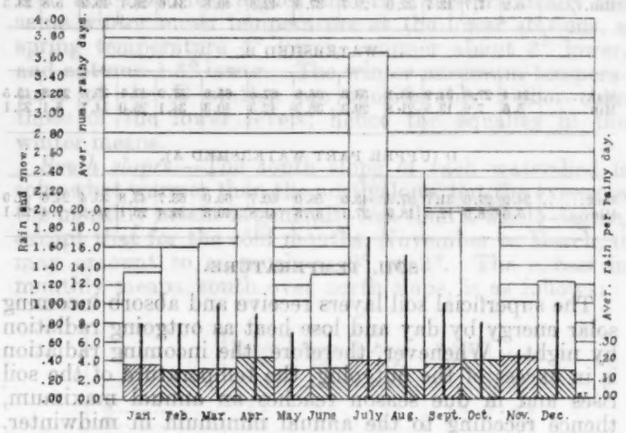

FIG. 13. Intensity of precipitation.

Snowfall.—While the snowfall forms a little less than 50 per cent of the total precipitation, it yields considerably more than 50 per cent of the run-off. The total precipitation in the months November to March, inclusive, is in the form of snow, and the precipitation of April is also 91 per cent snow. While a trace of snow may even fall in the summer months, the real transition months are June with 6 per cent of snow and October with 38 per cent. The snowfall of September is apt to be light, wholly disappearing before the cold-season snowfall sets in. The average depth of snow per season is 113.3 inches, with an equivalent water content of 9.94 inches. The range in depth from year to year is from 149.7 inches in 1916–17 to 80.7 inches in the following year. March, on the average of 9 years, is the month of maximum snowfall, 18.5 inches, with January, 17.9 inches, a close second; when, however, the months are corrected for unequal length, February ranks second with 17.98 inches and January third with 17.54 inches.

TABLE 7.

Watershed A. Average date of disappearance of snow and details of snow scales.				Watershed B. Average date of disappearance of snow and details of snow scales.			
No. of scale.	Direction of slope.	Angle of slope.	Average date of melting.	No. of scale.	Direction of slope.	Angle of slope.	Average date of melting.
		° ′				° ′	
4	N. 2 E.	42 00	May 15	1	N. 12 W.	15 30	May 16
7	N. 2 E.	25 20	May 10	10	N. 12 W.	26 50	May 26
1	N. 12 E.	34 10	May 16	5	N. 6 W.	36 40	May 11
10	N. 30 E.	13 50	May 17				
17	N. 40 E.	21 30	May 11	4	N. 22 E.	21 50	May 19
14	N. 46 E.	15 50	May 22	16	N. 26 E.	16 20	May 20
15	N. 52 E.	2 00	May 14	15	N. 29 E.	11 50	May 23
11	N. 72 E.	16 50	May 13	14	N. 52 E.	2 00	May 19
				11	N. 66 E.	22 10	May 12
8	N. 82 E.	9 30	May 11	13	N. 70 E.	9 10	May 12
6	N. 82 E.	33 50	Apr. 26				
9	N. 90 E.	11 20	May 7	9	S. 84 E.	10 50	May 16
				8	S. 74 E.	32 40	Apr. 23
13	S. 84 E.	10 50	May 13	2	S. 66 E.	25 30	Mar. 20
5	S. 40 E.	25 50	Mar. 26	12	S. 52 E.	21 40	Apr. 6
18	S. 36 E.	24 50	Mar. 7	6	S. 50 E.	26 50	Mar. 10
12	S. 32 E.	23 40	Mar. 16				
2	S. 70 E.	34 20	Apr. 1	7	Level		Apr. 24
3	Level		May 2	D	N. 50 E.	24 40	May 23
D	N. 50 E.	24 40	May 23				

Snowfall measurements.—The depth of snowfall and water equivalent, determined by weighing, is observed

daily about 9 a. m., at stations C, A–1, A–2, B–1, an B–2. It is determined at six-day intervals at the D station, and the amount for each day is apportioned from the measurements made on the two watersheds. Finally, beginning on March 1, to anticipate the melting season by a few weeks, the depth and density of the snow over the two watersheds is observed at the snow scales or show stakes which were installed at various places on both watersheds. There are 18 snow scales on A and 14 on B. Table 18 is a statement of the details of the location of each scale, to which has been added, for convenience in the discussion, the average date of disappearance of snow at each scale. The arrangement of the table is by slope rather than consecutively by the serial number of the snow scale.

ANALYSIS OF STREAM FLOW.

The general behavior of the streams.—The most casual observation of any of the stream-flow records obtained during periods of rain or melting snow shows the following points: (1) that stream A rises more rapidly than stream B: (2) That the maximum flow of A is reached sooner than that of B, and, therefore, during the early decline of A, stream B may be considerably higher; and (3) that before the flood has fully spent itself A may again attain the higher level, with a secondary and more steady volume of water.

These differences are all explainable by topography.

(1) Stream A receives a larger contribution of the first water falling directly into the stream in the case of rain, or melting along the stream banks in the case of snow, because it has a greater length of stream channel. With either rain or melting snow this advantage may be continued for many days, because the slopes through which the water must drain to reach the stream are both shorter and steeper than those on B. In other words, while B has 200 acres within an average distance of 950 feet of the stream, watershed A has an equal area within 670 feet. Since the flow down these slopes is relatively much slower than the flow in an open channel, it is evident that this width of slope has much more influence on the early flow than the length of the stream.

(2) After stream A has delivered its maximum flow, the longer slopes on B get into action, and not only are they later in delivering, but they may produce a higher flood because the extreme head of the watershed, being relatively near the dam, and hardly more distant from an open channel than the side slopes, delivers almost simultaneously with them. Thus B watershed, having more the shape of a bowl, within a few days of the flood crest may deliver a larger proportion of its total flood waters than A. Whether or not the crest flow on B is as great as on A will depend upon a number of factors, whether, for example, hourly, daily, or decade crests are referred to. A very rapid rise has the effect of amassing a large amount of water in stream A before B is well started, and of creating a higher short-period crest on A. On the other hand, the same rise will permit B to deliver a very large amount in the succeeding 10-day period and may cause a higher decade crest on B. Very different effects may, of course, be produced if the rapid melting of snow occurs after a period of slow melting which has disposed of much of the snow near stream A, since that *near* stream B does not melt so early.

(3) The higher flow of A late in the flood period (which may not be actually much higher when area is considered) is plainly due to the greater length of the watershed, or, in other words, to the slower draining out of the flatter ground more distant from the dam. This upper area, except during the heaviest melting period or in excessive rain, has no surface drainage, and hence its water is long in reaching the stream. The upper section of watershed A may practically be thought of as a separate area, such as does not exist with respect to stream B. It has a stabilizing effect on stream A.

On the other hand, although this is a separate consideration, this high area on watershed A probably contributes little or nothing to the stream in the winter period, when B is actually higher, and considerably higher per unit of area, than A. This high, relatively flat ground has the appearance of becoming very dry in the fall; when once covered with a blanket of snow, since it has no southerly exposures, there is practically no melting for months, and, therefore, although the ground is not frozen to any great depth, there is no water contributed from it.

The streams involved in this experiment are perennial, and after observing that there is melting of snow on south slopes throughout the winter, it is not difficult to calculate that the flow for any ten days, or in fact for any day or hour, is made up (1) of any current precipitation or melting which may reach the streams directly, and (2) of a slower movement of water from the soil. This movement from the soil will vary with each addition to the soil moisture. Its total contribution to the stream for any period will depend not only upon the average amount of moisture in the soil, but upon the distance of that moisture from the stream. Thus the relative amount of moisture at any two points not similarly situated with respect to the stream not only will vary with additions of precipitation, but will depend upon the time since the last addition of moisture.

Each of these variable factors is different for the two watersheds. Any attempt to figure the source of the water, even when we know its volume in the streams, therefore, becomes simply appalling when one considers all of the factors involved; and when it is remembered that the most important of these factors, the accurate measurement of the rainfall or the water contributed from melting snow, is difficult of accomplishment the preparation of a formula which will express streamflow looms up as an impossibility.

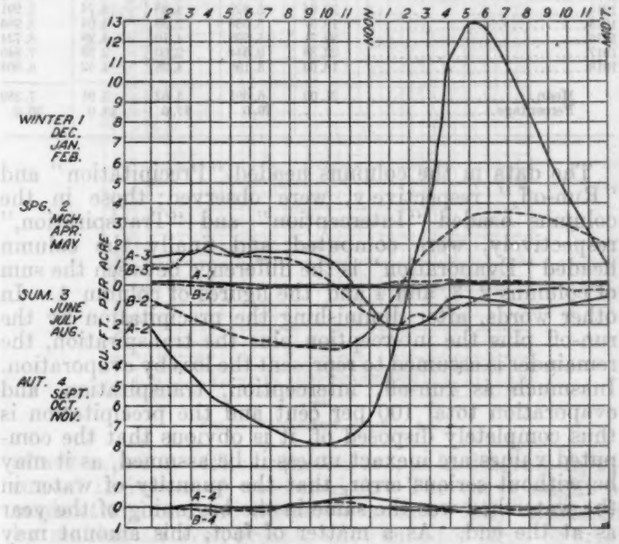
1 2 3 4 5 6 7 8 9 10 11 NOON 1 2 3 4 5 6 7 8 9 10 11 MID'T.
WINTER 1 DEC. JAN. FEB.
SPG. 2 MCH. APR. MAY
SUM. 3 JUNE JULY AUG.
AUT. 4 SEPT. OCT. NOV.
CU. FT. PER ACRE
A-3
B-3
A-1
B-1
B-2
A-2
A-4
B-4

FIG. 14. Diurnal variation in streamflow.

Diurnal variation in streamflow.—The diurnal variation in the flow of the two streams has been computed for the

eight years, July, 1911, to June, 1919, and the results have been plotted in figure 14. These curves are both instructive and illuminating—illuminating in that they show more clearly than would otherwise be possible the response of the streams to the meteorological conditions as modified by the physical characteristics of the two watersheds. The several monthly variations have been combined in a seasonal mean, each of which is based on approximately 20,000 observations.

The curve for winter (December, January, and February) is one of very small amplitude, but a weak response to the warm hours of the afternoon can be seen more pronounced on B than on A and the maximum seems to occur at 2 p. m. while on A it is deferred until 5 p. m.

The curve for spring (March, April, and May) is a composite made up of March and April, both of which show a weaker response to the increased insolation than May, the flood month. The dominant feature of the spring or flood curve, since all of the floods except the October rain floods are comprised within it, is the very wide variation of A as compared with B and the fact that the crest of the maximum daily discharge of the afternoon is reached at 3 p. m. and is sharply defined, whereas, the crest of the maximum daily discharge on B is not sharply defined and is reached at 6 p. m. instead of 3 p. m. Doubtless this is due to a greater time being required for concentration of runoff on B than on A, as elsewhere stated.

DISPOSITION OF PRECIPITATION.

Attempt has been made to dispose of the precipitation measured on the A watershed in accordance with the previous analysis. The results appear in Table 8.

TABLE 8.—*Disposition of precipitation, watershed A. Precipitation and run-off observed; interception, transpiration, and evaporation computed.*

Year.	(1) Precipitation.	(2) Run-off.	(3) Interception.	(4) Transpiration.	(5) Evaporation.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1912	21.30	8.368	3.61	3.92	5.402
1913	18.63	4.778	3.84	4.14	5.872
1914	22.64	5.629	4.28	4.74	7.991
1915	19.97	5.354	2.50	3.04	8.986
1916	22.71	5.596	4.10	4.28	8.734
1917	22.88	9.644	2.66	2.73	7.846
1918	18.90	3.196	4.28	4.52	6.904
Mean	21.00	6.081	3.62	3.91	7.389
Percentage		29.0	17.0	18.0	36.0

The data in the columns headed "Precipitation" and "Run-off," respectively, were observed; those in the columns headed "Interception" and "Transpiration," respectively, were computed; and finally the column headed "Evaporation" is the difference between the sum of columns 2, 3, and 4 and the figures of column 1. In other words, after diminishing the precipitation by the run-off plus the interception plus the transpiration, the remainder is assumed to represent the loss by evaporation. Inasmuch as run-off, interception, transpiration, and evaporation total 100 per cent and the precipitation is thus completely disposed of, it is obvious that the computed values are inexact unless it be assumed, as it may be without serious error, that the quantity of water in the watershed was the same in the beginning of the year as at the end. As a matter of fact, this amount may vary somewhat from year to year. It is never very large, except as a result of heavy or continued rains. The disposition of the precipitation is graphically presented in figure 15.

STREAM-FLOW PRECIPITATION RELATIONS FOR THE TWO WATERSHEDS.

The remainder of the report is devoted to an attempt to show the relation between precipitation and run-off as influenced by the many factors which enter into the problem and to express these relations graphically in a set of diagrams accompanied by certain precepts which are to control the interpretation of the stream-flow data in future studies. The object of this analysis is, of course, to reach a conclusion as to the best method of determining the most probable run-off of stream B had denudation not taken place. The crux of the experiment lies in the accuracy with which that value is determined.

Stream-flow relations have been analyzed for a number of periods, but space does not permit reproducing the analyses of but three of these periods, (1) for the year, October to October, (2) the spring flood, and (3) the end of the flood period. The arguments, data, and diagrams for these three periods form the concluding part of this abstract and are given verbatim from the full report.[1]

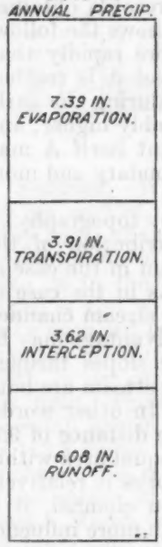

FIG. 15. Disposition of precipitation.

Relations of the streams for whole years.—The precipitation and run-off data for the eight years ending September 30, 1919, are given in Table 9, together with calculations showing the relation of total run-off of each watershed to precipitation.

On the mean amounts of precipitation for the two watersheds for eight years are almost the same, but in individual years they show considerable variation. This raises the question as to whether one watershed may actually receive more precipitation than the other, or whether the differences noted are due solely or largely to peculiarities of gage-catch. No doubt in some summer rains, which in mountainous regions are often very local in character, one watershed may receive more precipitation than the other, and for the whole year 1912–13 it is evidenced by both the precipitation and streamflow records that watershed B must have received appreciably more than watershed A. In the case of winter snowfall, however, since the storms often last for many hours, there is practically no opportunity for differences in the actual fall of the two areas. Yet the winter months show fully as great variations in catch as do the summer months. The conclusion is obvious that differences between the two areas in matters of precipitation are more apparent than real.

In view of these facts, it seems more desirable, as well as simpler, to base all comparisons of streamflow and precipitation on the precipitation of A watershed alone. It might be argued that the average of the two would be even better. The answer is that while discrepancies between the two have, in the past, pretty well evened up over a long period, still there is no assurance, now that watershed B is denuded, that a catch can be obtained, with the greater exposure of gages to the wind, at all comparable to that obtained on A.

The use of the single record can not be seriously objected to when it is considered that at the lower end

[1] A limited number of copies of the full report can be obtained from the Superintendent of Documents, Washington, D. C., at the nominal charge of 50 cents.

of watershed A there is the choice of the better catch of two gages, and this value is averaged with the catch of a third gage at the head of the watershed.

TABLE 9.—*Precipitation and run-off for years beginning Oct. 1.*

Year	Precipitation (inches over watershed).			Run-off (inches over watershed).				Proportion of precipitation appearing as run-off.		$B/A - R/Pa$.
	For the year.		Difference $B-A$.	For the year.		Difference $B-A$.	Ratio B/A	R/Pa.		
	A.	B.		A.	B.			A.	B.	
1911–12.....	21.30	21.49	+0.19	8.368	8.367	−0.001	1.000	0.393	0.393	0.607
1912–13.....	18.63	19.66	+1.03	4.778	5.213	+ .435	1.091	.256	.280	.834
1913–14.....	22.64	21.84	− .80	5.629	5.551	− .078	.986	.245	.245	.737
1914–15.....	19.97	19.85	− .12	5.354	5.405	+ .051	1.011	.268	.271	.743
1915–16.....	22.71	23.13	+ .42	5.596	5.553	− .043	.992	.246	.245	.746
1916–17.....	22.88	22.78	− .10	9.644	9.839	+ .195	1.020	.422	.430	.598
1917–18.....	18.90	18.85	− .05	3.196	3.531	+ .335	1.105	.169	.187	.936
1918–19.....	21.13	21.15	+ .02	6.081	5.968	− .113	.981	.288	.282	.693
Means...	21.02	21.09	+ .07	6.081	6.178	+ .098	1.023	.2864	.2916	.....
Sums....	168.16	168.75	+ .59	48.646	49.427	+ .781	8.186	2.291	2.333	.....

The following points with reference to the data of Table 9 are noteworthy:

1. The precipitation is unusually uniform from year to year.

2. The amount of water discharged by stream A varies greatly from year to year, and may be from 17 to 42 per cent of the precipitation.

3. The amount of water discharged by stream B is, on the whole, about 2 per cent greater than that for stream A. This immediately suggests that evaporation must be the less on B, either by reason of the cover conditions or because B has a deeper and better storage reservoir, or both.

4. On closer examination (see diagram A) it is seen that the ratio of B to A total discharge is highest in the years when, either because of relatively low precipitation or other causes, the total streamflow is least. In the case of the year 1912–13 it is probable that the very high ratio B/A is due in part to an actual excess of precipitation on B, and some allowance should be made for this.

The relation of the two streams approaches unity only in years whose precipitation and evaporation tendencies are about normal. On the other hand, B streamflow again tends to become greater than that of A when the total amount discharged by either is unusually great. The two years exhibiting this are 1911–12 and 1916–17. In the former there was a heavy spring flood, as well as a very considerable discharge from October rains. In the second case the flood was unusually large, comprising over 70 per cent of the total run-off for the year.

In such cases it is evident the storage facilities of both watersheds may be filled to capacity, and watershed B, being able to deliver a larger amount of water for streamflow in a given time, naturally makes the better showing.

Although these relations of the two streams do not express themselves as a simple curve, they are so simple that the acceptability of the relations as shown by diagram A can hardly be questioned. On the other hand, the true curve for the data represented by diagram A (fig. 16) is almost impossible to draw. It has, therefore, been sought to express the causes of variation in the ratio B/A, as described above, by introducing another element. The two years of greatest stream discharge were also the two years in which the ratios of discharge to precipitation were highest, while the other extreme of the diagram represents a year in which the relative amount of stream-flow was excessively low. It is, therefore, suggested that the amount of run-off relative to precipitation has a direct bearing on the relation of the two streams for whole years. Whenever the streamflow is *relatively* high (or the evaporation a relatively small percentage of the whole disposal), then the ratio of B to A discharge will be heightened.

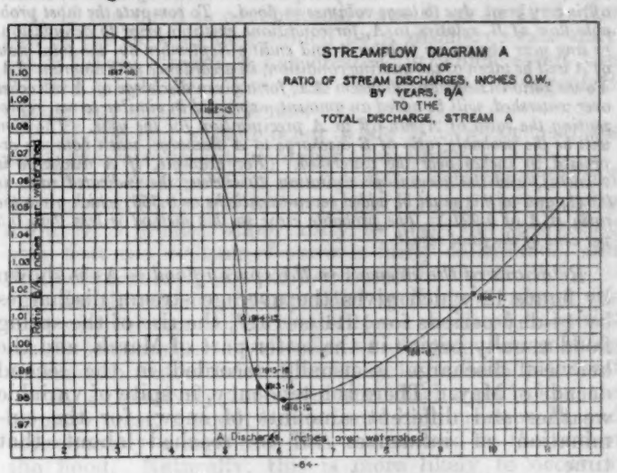
STREAMFLOW DIAGRAM A
RELATION OF
RATIO OF STREAM DISCHARGES, INCHES O.W., BY YEARS, B/A
TO THE
TOTAL DISCHARGE, STREAM A
B/A, ratio of discharges, B to A
A Discharge, inches over watershed
-64-

FIG. 16. Streamflow, diagram A.

In the last column of Table 9 the data for diagram AA (fig. 17) have been worked out. The abscissæ are obtained by deducting from the ratio B/A the ratio, in corresponding terms, between the run-off and precipitation

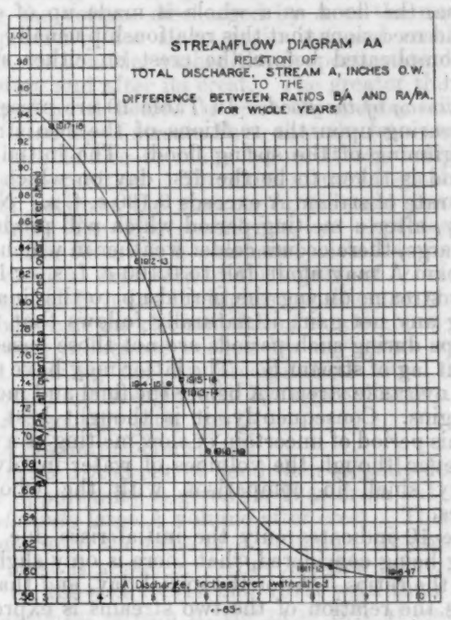

FIG. 17. Streamflow, diagram AA.

of watershed A. The ordinates are, as in diagram A, the run-off in inches of watershed A. The curve might be made straighter, and the relations more fully expressed, by making an even greater allowance for large or small ratio P/R (say one and one-half times), but the use of the straight term P/R brings the data within the range of easy handling. (Figs. 16 and 17.)

The relations may be summarized for reference in the future, as follows:

RULE 1. *Between the extremes of 18 and 23 inches of precipitation, and of 8 and 10 inches of discharge from Watershed A, it is recognized that the ratio of annual discharges, B/A, should never be greater than 1.11 nor less than 0.98, with a mean value of 1.02. The ratio is slightly less than 1.00 only when there is about a normal balance between streamflow and precipitation, represented by 5 or 6 inches for the former and 20 to 22 inches for the latter, and increases either when precipitation and run-off are low, or run-off is very great, due to large volumes in flood. To compute the most probable flow of B, relative to A, for conditions existing prior to denudation, or any year beginning October 1 and ending September 30, the total flow of A will be taken as the guiding condition, in accordance with diagram AA. To the ratio indicated on diagram AA, for a given discharge of A in inches over watershed, will be added an amount, expressed in similar terms, representing the ratio of A run-off to A precipitation for the year. The sum will be the probable ratio of B discharge to A discharge, when both are expressed in inches over the watershed. (For example, if A discharge is 7 inches, and the annual precipitation 20 inches, the indicated ratio is 0.641, and to this must be added seven-twentieths or 0.350, which gives the ratio B/A of 0.991.) The probable error in this method is less than 0.5 per cent of the final result.*

Relations of the streams in the spring flood.—As is shown by figure 12 which gives the average stream discharges by 14-day periods for 1911 to 1917, the rise of the spring flood usually begins in the latter part of March, and the heaviest discharge is usually recorded in the second decade of May. There is a tendency, in spite of variable weather and different amounts of snow, for the culmination of influences to be reached about that time.

In spite of the fact that successive floods show similar characteristics, especially in the general shape of the A and B curves, it has been found impossible to establish any fixed relations between the rates of discharge of the two streams at intermediate stages in the flood. While, as has been stated, stream B lags behind stream A during any rise, the flood as a whole is made up of so many rises and recessions that this relationship usually becomes very complicated before the crest on either stream is reached.

Beginning of the flood.—In Table 10 are presented the data bearing upon the realtions of the two streams at the beginning of the spring flood. The initial date of the flood is taken to be the first day on which the discharge rate of stream A exceeds 0.100 c. f. s. Not infrequently, after a melting period which will produce such a discharge, there occurs colder weather in which the rate for stream A may again fall to 0.100 c. f. s. or less. As neither stream, during the period up to the final rise, is making any net gain, it naturally follows that the relationships during such periods are not those based on the inherent lag of stream B. The latter may have opportunity to overtake stream A before the final and more rapid rise begins. Consequently, it is thought best to consider this period of uncertain or slow melting as a separate stage, even though the volumes of water involved may be very small in comparison with the whole flood volumes.

Table 10 indicates only the initial rises due to snow melting being considered, that there is only slight variation in the ratios B/A for the initial day, and that on the average the relation of the two streams is expressed by unity. On plotting the ratios, however, in relation to the height attained by stream A on this initial day, it is found that there is a fairly consistent relationship. It is probable that the relationship is controlled by the *rate of rise* rather than the head attained by stream A, but we have been unable to find a key which exactly fits the situation.

TABLE 10.—*Conditions at beginning of flood.*

Year.	Initial date.	Discharge on initial date.				
		c. f. s.		Inches O. W.		
		A	B	A	B	Ratio.
1912	Mar. 6	0.102	0.091	0.0109	0.0108	0.991
1913	Apr. 29	.106	.094	.0113	.0111	.983
1914	Apr. 5	.109	.113	.0116	.0135	1.155
1915	Apr. 12	.101	.098	.0108	.0117	1.082
1916	Mar. 10	.108	.096	.0116	.0115	.989
1917	Mar. 29	.119	.092	.0127	.0109	.860
1918	Apr. 23	.108	.092	.0115	.0110	.958
1919	Apr. 4	.107	.094	.0114	.0112	.978
Averages	Mar. 30	.1075	.0962	.01148	.01146	1.000

Year.	Initial date.	Period of uncertain melting.				Discharge on and after highest day.		
		Final date.	Total volume.			Amount.	Number of days.	Amount corrected [1] for number of days.
			A	B	Ratio.			
1912	Mar. 6	Apr. 2	0.2822	0.3082	1.092	0.0852	8	0.0212
1913	Mar. 29							
1914	Apr. 5							
1915	Apr. 12	Apr. 17	.0632	.0748	1.183	.0425	4	.0105
1916	Mar. 10	Apr. 7	.3753	.3878	1.033	.2248	18	.0808
1917	Mar. 29	Apr. 8	.1021	.1155	1.131	.1021	11	.0141
1918	Apr. 23							
1919	Apr. 4	Apr. 11	.0841	.0911	1.082	.0727	7	.0167
Averages	Mar. 30				1.1044			

[1] Reduce amount 0.008 for each day, including and following highest day of period.

It is also to be noted that in every listed period following the initial dates, when the streams fell back, the discharge of B exceeded that of A by an amount not varying greatly from 10 per cent. It is practically certain that the relations during such a period depend largely on the opportunity given for stream B to overtake and exceed stream A in delivery. The longer the period after A has reached the highest point, the greater should be the ratio B/A. But this ratio will tend to be lowered, other things being equal, if stream A has reached a relatively high point and discharges a relatively large volume thereafter. The most consistent relationship is found, then, by plotting the ratios B/A for the whole period against the volume discharge of A, with a minus correction for each day elapsed from the highest day to the end of this period of uncertain or suspended melting.

The relations at the beginning of the flood period may be formulated as follows:

RULE 2. *The ratio of B discharge in inches over watershed to the similar discharge for A on the first day of the spring rise in which stream A shows a rate of more than 0.100 c. f. s. is on the average 1.00, but may vary in different years by plus or minus 15 per cent. To determine the suppositional ratio after denudation, reference will be made to the discharge of stream A in c. f. s., and the corresponding value will be read from diagram B (fig. 18).*

RULE 2A. *In the event that the discharge rate of stream A, after the initial date of the flood, should again fall to or below 0.100 c. f. s., the ordinary relationship of the two streams in the early rise, with A leading B, may be reversed, so that on the average B will discharge about 10 per cent more for the whole of such a period. To determine the suppositional ratio B/A for such a period, from the initial day to the day next preceding the final rise above 0.100 c. f. s. (both dates included) in inches over watersheds, reference will be made to the discharge of stream A for that portion of the period beginning with the day of greatest discharge. The computed flow of A in inches over watershed will be reduced 0.008 inch for each day of the period including and following the crest day. The value thus obtained will be referred to diagram BB (fig. 19), from which the ratio B/A for the whole period may be obtained.*

End of the flood.—The relations existing between the two streams at the end of the flood are important, not only in allocating the volume which has been discharged but also because this relation is reflected throughout the summer period.

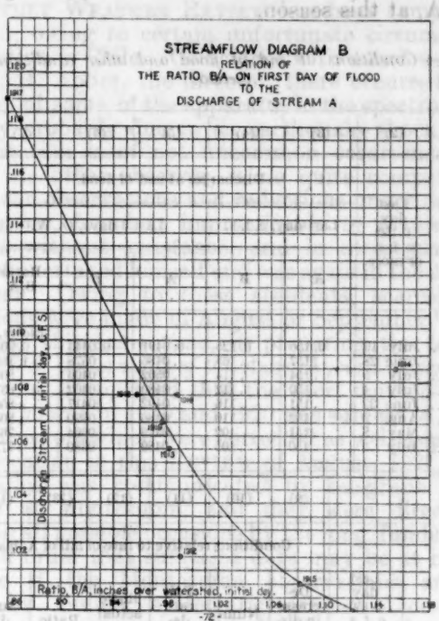
STREAMFLOW DIAGRAM B
RELATION OF
THE RATIO B/A ON FIRST DAY OF FLOOD
TO THE
DISCHARGE OF STREAM A
Discharge, stream A, initial day, c.f.s.
Ratio B/A, inches over watershed, initial day
-72-

FIG. 18. Streamflow, diagram B.

The end of the flood is taken to be the last day on which stream A has a discharge of 0.150 c. f. s. or more. Should such a discharge occur after a dip below 0.150, it would be allocated to the summer period. One exception has been made in order to give some semblance of character to the very small flood of 1918. Here the crest day showed a rate of only 0.157 c. f. s. for A, the following day 0.148, and the third day 0.151. The last was taken as the closing day of the flood.

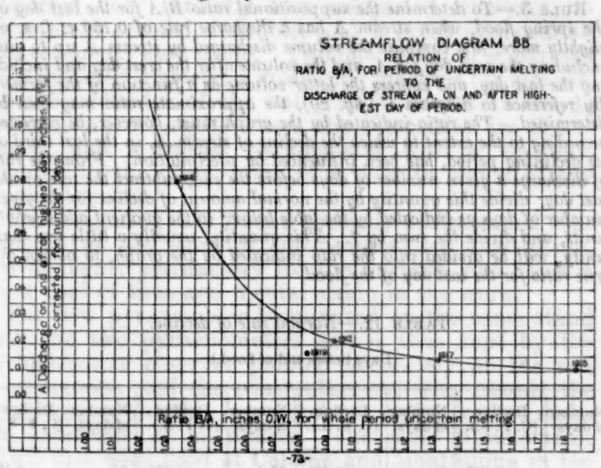
STREAMFLOW DIAGRAM BB
RELATION OF
RATIO B/A, FOR PERIOD OF UNCERTAIN MELTING
TO THE
DISCHARGE OF STREAM A, ON AND AFTER HIGHEST DAY OF PERIOD.
A Discharge on and after highest day shown, D.C.
corrected for number of days
Ratio B/A, inches O.W. for whole period uncertain melting
-73-

FIG. 19. Streamflow, diagram BB.

In general, the relation between the streams at the arbitrary date is seen to be controlled by the extent to which watershed B has had opportunity to exercise its ability to drain out the surcharge of water from snow melting more rapidly than watershed A. The extent to which this has occurred and the extent of depression of the ratio B/A would, naturally, depend very largely on the length of the draining-out period. On trial, however, it is found better to express this period in volumes discharged rather than in days.

There are four conceivable and rather distinct sets of conditions which produce the relation at the end of the flood:

1. If the flood is exceptionally small, as in 1918, the end of the flood as determined by A discharge rate may occur before stream B has crested, in which event the relation would be a low ratio B/A due to the lag of B during any considerable rise.

2. If the end should occur while B is at or near its crest, the ratio might be higher than unity.

3. From this point on, greater flood volumes will tend to produce lower and lower ratios B/A at the end, by allowing B greater opportunity to drain out, providing only that the melting of snow is fairly continuous, and produces a sharply conical flood crest on stream A.

4. In the event of suspended melting at about the time when stream A has crested (as a result of daily and hourly temperature distribution as affecting snow melting on the two watersheds), there may be a secondary crest on A, a relatively large volume discharged after the primary crest, a much belated and high crest on B, and consequently a high rate B/A maintained to the end of the flood. Naturally, this is more likely to occur in years when there is a large volume of snow to be melted, so that in extension of the remarks under the preceding paragraph there is still a possibility of an increasing ratio B/A with floods of large volume.

The preceding conditions become less confusing and less conflicting in their actual effects if, instead of considering the volume discharged by A as the measure of the opportunity for B to drain out and reach a low position, we consider rather the proportionate discharge of A before and after its crest. The greater the amount discharged by A before its crest the greater will be the accumulated lag of stream B, so that the latter may have a considerable rise to make before it can subside to a subordinate position. Therefore a more logical relation is found between the streams in different years if the opportunity for B's subsidence, as expressed by A volume after its crest, is compared with the opportunity for B's delay as expressed by the volume of A before crest.

In general B holds its highest position at the end of the flood when the rise and fall of A are about symmetrical, being influenced neither by any great amount of belated melting nor by precipitation after the crest. This condition is expressed by approximately a unity ratio, $\frac{\text{A discharge after crest.}}{\text{A discharge before crest.}}$

The ratio B/A at end of flood then steadily decreases if greater opportunity is given for B to drain out, as shown by a *relatively* large A volume after crest. This decrease continues until the ratio of A volume after crest to that before crest is about 2:1. Beyond this point, as represented by the years 1917 and 1913, with their flattened flood crests for stream A, the ratio B/A at end of flood must again rise. Such a flattened crest on A is certain to mean belated melting, which in effect eliminates the opportunity for B to overtake and drain out in advance of A.

In addition to the above-mentioned influences on the relative positions of the two streams at the end of the flood, the amount of precipitation occurring during the period of decline of both streams must have its effect.

Precipitation, especially toward the end of the flood period, tends to increase the ratio B/A. This is especially noticeable in the graph for the year 1913, when, but for continuous rains, the flood would have ended nearly a month sooner, and with a ratio B/A of about 1:1, in spite of the heavy flow after A crest. It is also noticeable in 1912, when there was considerable rain near the end of the flood. That falling earlier is, apparently, united with the water from melting snow, and merely increases the volume of flow after the crest. That falling late probably reaches the streams directly and has an independent effect.

Various methods of correcting for this rain factor suggest themselves, and a number have been carefully gone into. The objection to any direct use of the precipitation record is that the influence of rain is so variable, according to continuity, dryness of the ground at the time, and other conditions. It seems best, therefore, to estimate the possible effect of rain on the final ratio B/A, by noting its effect first on the flow of A. The last one-third of the period of decline for stream A has been chosen as the period in which the influence of rain is most likely to be felt. It is not suggested that earlier rain has no influence, but whatever that influence is, it is likely to be obscured by the later conditions.

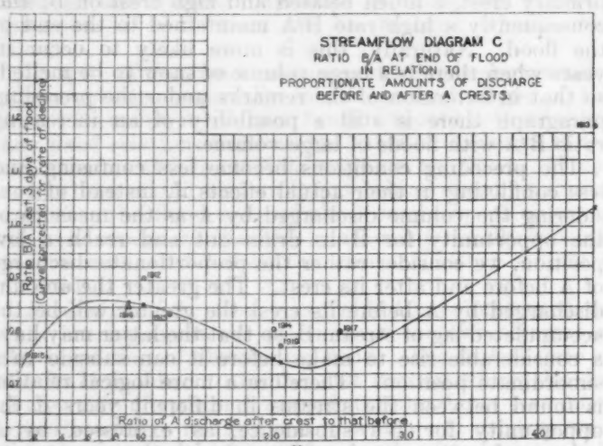
STREAMFLOW DIAGRAM C
RATIO B/A AT END OF FLOOD
IN RELATION TO
PROPORTIONATE AMOUNTS OF DISCHARGE
BEFORE AND AFTER A CRESTS.
Ratio B/A last 3 days of flood
(Curve corrected for rate of decline)
Ratio of A discharge after crest to that before

FIG. 20. Streamflow, diagram C.

The rate of decline of stream A in this last-third period affords the best index of the effectiveness of rain. As a basis of comparison, the daily rate of decline for discharges from 0.150 to 0.400 c. f. s., in periods not influenced by rain has been computed. These rates are, of course, influenced by cloudiness, evaporation, etc., and vary a good deal from day to day. Using the mean curve, it is possible to figure up from the rate of 0.150 c. f. s. by adding the daily changes, and to show quite closely what the rate of discharge would have been 15, 20, or 25 days before the rate of 0.150 c. f. s. was reached, if uninfluenced by rain. Thus, in the last 20 days of a flood, the "normal" decline would be from a head of 0.268 to a head of 0.150 c. f. s., or a change of 0.118 c. f. s.

To such a figure as the last, varying according to the length of the period, may be compared the actual decline of any given year. As example, the decline in 1912, for the last 20 days, was 0.074 c. f. s., which, compared with a "normal" of 0.118 c. f. s., gives the ratio 0.626 as expressing the influence of precipitation on the discharge of A. The smaller this decimal, or the greater the effectiveness of the precipitation, the higher the ratio B/A at the end of the flood may be expected to be. It has been found by trial that the influence of precipitation on stream B is about one-seventh more than its influence on A, at this season.

TABLE 11.—*Conditions at end of flood and other conditions relating thereto.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year.	Last day 0.150 c. f. s. or more.	Discharges at end of flood.					Ratio A discharge after crest to that on and before crest.
		Last day, c. f. s.		Last 3 days, O. W.[1]			
		A	B	A	B	Ratio B/A	
						Inches.	
1912	July 19	0.156	0.125	0.0491	0.0443	0.903	1.033
1913	June 28	.157	.165	.0486	.0578	1.188	4.420
1914	July 5	.154	.114	.0502	.0406	.808	2.011
1915	July 4	.150	.112	.0480	.0402	.837	1.227
1916	June 22	.151	.116	.0492	.0417	.850	0.918
1917	Aug. 2	.152	.110	.0486	.0390	.804	2.504
1918	May 8	.151	.102	.0479	.0364	.761	0.158
1919	July 5	.150	.105	.0489	.0380	.777	2.061

		(9)	(10)	(11)	(12)	(13)	(14)	(15)
Year.	Last day 0.150 c. f. s. or more.	Conditions relative to rate of fall of A, last third.						
		Decrease in discharge rate c. f. s.	Number of days.	Full rate decrease this period.	Ratio actual to full decrease.	Ratio plus 6.	Sum divided by 7.	Corrected ratio column.
1912	July 19	0.074	20	0.118	0.626	6.626	0.2466	0.855
1913	June 28	.016	24	.162	.099	6.099	.8713	1.035
1914	July 5	.064	18	.099	.647	6.647	.9496	.767
1915	July 4	.077	15	.076	1.013	7.013	1.0019	.839
1916	June 22	.073	14	.069	1.058	7.053	1.0083	.857
1917	Aug. 2	.101	25	.175	.577	6.577	.9396	.755
1919	July 5	.083	20	.118	.703	6.703	.9576	.744

[1] To avoid possible marked effects of rain on the last day, use the sum for three days, including one before and one after the final day.

RULE 3.—*To determine the suppositional ratio B/A for the last day of the spring flood, when stream A has a discharge rate of 0.150 c. f. s. or slightly more, first compute the volume discharged by stream A up to and including the crest day for A, and the volume after the crest day and including the last day, and express the latter volume as a function of the former. By reference to diagram C (fig. 20), the approximate ratio may then be determined. The ratio indicated by the graph must, however, be corrected according to the extent to which the decline of stream A, in the last third of its declining period, has been influenced by precipitation. From the rate of discharge a given number of days before the end, subtract the rate on the last day; divide this quantity by the normal amount of decline for the given number of days as indicated by the table below; to the quotient add 6 whole units, and divide the sum by 7. This quantity, usually a little less than unity, will be divided into the rato indicated by the graph, to obtain the true ratio for the last day of the flood.*

TABLE 12.—*Normal rate of decline.*

[Days before end of flood.]

Number of days.	Decline (C. F. S.).	Number of days.	Decline (C. F. S.).	Number of days.	Decline (C. F. S.).	Number of days.	Decline (C. F. S.).
1	0.003	9	0.039	17	0.091	24	0.162
2	.007	10	.044	18	.099	25	.175
3	.011	11	.050	19	.108	26	.....
4	.015	12	.056	20	.118	27	.....
5	.019	13	.062	21	.128	28	.....
6	.024	14	.069	22	.139	29	.....
7	.029	15	.076	23	.150	30	.....
8	.034	16	.083				

RECENT IMPROVEMENTS IN SOLAR RADIATION OBSERVATIONS AT CALAMA, CHILE.

BY C. G. ABBOT, ASSISTANT SECRETARY.

[Smithsonian Institution, Washington, D. C., Jan. 25, 1922.]

The publication of solar radiation observations in the MONTHLY WEATHER REVIEW has been temporarily suspended, owing to certain unfortunate circumstances at the station in Chile. Coincident with a serious illness of Mr. L. H. Abbot, the director, there occurred a displacement of some of the apparatus in the spectrobolometer, very probably due to an earthquake shock, which at that station is of not uncommon occurrence. Mr. Greeley, the other observer, while quite competent to carry on the observations and reductions under ordinary circumstances, found it impracticable to readjust the apparatus without assistance, and in attempting this Mr. Abbot overtaxed himself and was again in the hospital for a time. Owing to these accidents, scarcely any observations were made in August or September.[1]

At about this same time, in preparing the text for Volume IV of the *Annals of the Astrophysical Observatory*, now in press, it appeared that the short method as employed at Calama in 1919 and 1920 was subject to certain systematic errors which were corrected as well as possible in a publication in this REVIEW of August, 1921. This circumstance was communicated by telegraph to the observers at Montezuma, and they were directed to observe on all possible occasions by the long, fundamental method in order that sufficient data may be at hand to determine if the Montezuma observations are also affected by similar systematic errors. Accordingly, beginning with October a very large proportion of the observations has been made by the fundamental method in addition to those made by the short method.

In view of all the circumstances, it seemed best for the writer to make a visit of inspection to the Montezuma observatory, and he sailed for this purpose on the 26th of October, 1921, returning January 4, 1922. The writer was at the station at Montezuma from November 15 to December 14, 30 days altogether, during which observations of the solar constant of radiation were made on 26 days, all of the apparatus employed in the work was inspected very carefully and readjusted wherever readjustment seemed desirable, and a great many small improvements were made. Two new pieces of apparatus were installed, namely, a measuring machine for measuring the ordinates of the bolographic curves at the 36 different wave lengths where the intensities are determined, and a special pyranometer with a vestibule adopted to the observation of a definite region of sky around the sun.

The measuring instrument, specially designed and constructed at the shop of the Smithsonian Institution, proves highly satisfactory for the purpose, and saves a great deal of time and mental strain in the work.

The new pyranometer is mounted on the same stand with the two pyrheliometers and is thus kept by the pyrheliometer observer pointed accurately at the sun continuously, and the other observer, who records the brightness of the sky, has merely to pull a cord to make the exposures as he desires. The older pyranometer which had been used at Calama and Montezuma in the short-method work since July, 1919, was provided with a polished metal thimble close to the glass hemisphere, in which was an aperture which exposed the central part of the strip to the sky for some 19° of angle on every side of the sun. The new instrument has a vestibule about 15 cm. deep which exposes the strip to a somewhat smaller angular aperture of sky. It has this great advantage, that owing to the depth of the vestibule all parts of the short sensitive strip of the pyranometer look out on almost identically the same regions of sky. In the older instrument, with its small spherical thimble, the ends of the pyranometer strip, on the contrary, look on quite different regions of sky from the middle. This may have led to erroneous values, especially at the larger air masses and on days when the clouds were present at no very great distance from the sun. It is believed that the new instrument will lead to short-method values which are of a higher degree of accuracy than the old. A great number of observations are being made to compare the results by the two instruments, so that there shall be no break in the continuity in passing from the one to the other.

Pyrheliometer S. I. No. 5, the property of the Bureau of Plant Industry, United States Department of Agriculture, was kindly loaned to the writer, compared at Washington with pyrheliometer A. P. O. 8^{bis}, and compared at Montezuma with pyrheliometer No. 30. It is intended to complete the chain of comparisons by further work at Washington, at Mount Harqua Hala, and again at Washington, so as to tie together our whole system of solar radiation measurements. Preliminary results of the work thus far indicate that the pyrheliometers in use at Montezuma do not differ by as much as 1 per cent in their present constants from those determined for those instruments in 1917 before they were carried on the expedition.

During a part of the time when the writer was at the station, the sky was of a very high order of uniformity and cloudlessness, and after having gotten the entire apparatus into the most perfect possible condition some long-method observations were made which seemed to be of a higher order of accuracy than any which had ever been made at any of the Smithsonian stations in all the years of our observation. Days of this character are November 26 and December 2, in which as many as 18 or 20 out of the 36 logarithmic extrapolations for different wave lengths were rated as E^3, since the straight line represented by the fine wire of the slide-rule extrapolating machine covered all 6 points of observation for each of these wave lengths. I am convinced that the means of determining the solar constant of radiation at Montezuma are now superior to any that have ever been employed by us hitherto, and that no more suitable station for the work could be found in the whole world. I have the greatest confidence that the observations from now on will take on a higher character for accuracy than any we have hitherto published.

It is a pleasure to bear a tribute here to the work of former Director A. F. Moore in his design and accomplishment of the removal of the observing station from Calama to Montezuma. Nothing could exceed the excellence of his choice of the station and the perfect adaptation of the ground to the purposes in view. The group of buildings containing the observers' quarters, the shop, and the garage lie at the head of a little canyon about 15 kilometers from Calama and reached by a road of such

[1] See this REVIEW, pp. 670-671.

gradual slope that the automobile can go on high gear right up to the buildings themselves with a very considerable load, and this without any expense whatever for road construction. The high elevation to the west of the observers' quarters cuts off the strong west winds of the afternoon, and as there are no winds at all, or scarcely perceptible ones, during the first four hours after sunrise, the observers occupy a most fortunate position compared, for instance, with the mining camp at Chuquicamata, where the wind blows very hard a large portion of the time. Furthermore, the soil, although absolutely barren of vegetation, seems to have elements of such a physical and chemical character that even in the afternoon, when the wind is high, scarcely any dust is carried by it.

From the observers' quarters a walk of from 5 to 10 minutes leads to the cave at the top of the mountain, some 300 or 400 feet higher up, where the spectrobolometric apparatus is installed. By means of wiring, it is arranged so that the storage batteries may be charged from the shop near the observers' quarters, and also so that the observer may throw in the bolometer battery current from his couch as soon as he wakes without having to go up the hill for that purpose. It is only necessary, in short, to go up the hill twice during the day: once for the series of observations, and again at 8:30 p. m. to signal by means of a small searchlight the weighted mean solar constant value to Calama, from whence it is forwarded by telegraph, at the cost of the Argentine Government, for use by the Weather Bureau at Buenos Aires.

Mr. Moore's installation of the spectrobolometric outfit in the cave was a very happy thought, for which he ascribes credit to his brother, Mr. E. B. Moore. The temperature there is almost invariable, a circumstance which leads to the utmost freedom of the spectrobolometer from drift. This freedom is indeed so complete that a steel straightedge laid from end to end of the bolometric curves almost invariably bisects all the marks produced by the insertion of the shutter in front of the slit to get the zeros of radiation. It is seldom indeed that a "drift" exceeding 2 millimeters occurs in these plates. The extraordinary character of these two statements may be better understood when it is said that computation shows that on these plates a change of position of one-tenth of a millimeter corresponds to one-millionth of a degree relative change in temperature of the two bolometer strips. Sometimes a so-called "battery curve" is made, that is to say, a curve representing the position of the galvanometer when no radiation is falling upon the bolometer, and such curves often show no more than 8 or 10 occasions, during the whole time of 7 minutes required for a complete bolograph of the solar spectrum, when the bolometer strips change relative temperature by as much as one-millionth of a degree, and none of changes as great as a hundred-thousandth of a degree. These conditions would have been a joy to the late Prof. Langley, who used to tell the writer that in his observations on Mount Whitney and at Lone Pine the galvanometer spot would drift off of a scale a meter long in a minute of time.

STRUCTURE OF COMPOUND DEPRESSIONS.

By H. FICKER.

[Reprinted from *Science Abstracts*, Oct. 31, 1921.]

The pressure changes at the earth's surface during the passage of a depression are only partly accounted for by the spreading of cold waves of polar origin in the lower troposphere, and their interaction with warm equatorial currents.

Both mountain and aerological observations indicate that pressure changes are large even at high levels, and the author pictures three layers of the atmosphere as each playing a distinct part—(1) the lower half of the troposphere where cold polar and warm equatorial currents interact, (2) the lower half of the stratosphere where "cold" equatorial and "warm" polar currents interact, (3) the upper troposphere where there are no marked horizontal tmperature gradients.

The essential feature of the hypothesis is that the effects in the stratosphere are regarded as thermal rather than dynamical. The ensemble is termed a "compound depression" and most depressions are of this type. The pressure wave recorded by a barograph at the surface is compounded of that due to (1) and that due to (2) which is transmitted unchanged by the intermediate level (3). The depressions in the stratosphere and lower troposphere, though related, in general move with different velocities, and this may produce a variety of different curves at places at the surface.

This and other consequences of the hypothesis are considered in some detail.—*M. A. G.*

ON THE STRUCTURE OF ANTICYCLONES AND CYCLONES IN THE STRATOSPHERE OVER EUROPE.

By FELIX M. EXNER.

[Translation by W. W. REED, Weather Bureau, Atlanta, Ga., Jan. 5, 1922.]

Lately, A. Schedler (1) correlated the observations of air pressure and temperature aloft, as obtained in the international series of flights, with the regions of rise and of fall in air pressure at the ground. It appeared that the front and rear sides as well as the center of regions of fall and of rise in pressure are characterized by transitory pressure and temperature changes differing in marked degree one from another. Since Schedler summed up the changes from one day to another he was able to derive approximate values of pressure and temperature distribution in cyclones and in anticyclones when lying side by side.

In this way he found a mean distribution of pressure and temperature along a cross-section from west to east through a region with both high pressure and low pressure; to be sure no claim can be made to great accuracy, and especially in amplitude, it is certainly too much reduced, since determination of means diminishes the extremes. However, it is plainly seen how over high pressure at the ground the pressure is high in the higher strata also, but the extreme shifts toward the west (backward inclination of the "axes" of cyclone and anticyclone); and it is plainly seen how above it (high pressure at the ground—*Translator*) the stratosphere lies high, while above high temperature at the ground the temperature remains high even up to the stratosphere, in which the extreme inclines somewhat forward (toward the east); however, over the warm stratum there lies cold stratospheric air. Exactly the opposite distribution is found with opposite sign (of departure).

This structure is essentially in complete agreement with the Dines's correlation factors relative to the free atmosphere.

A finding that appears interesting to me is made when Schedler's pressure and temperature values are presented together as has been done in the following figure. (Fig. 1.)

Here Schedler's figures (3 and 4) are placed one above the other; the values p_0 and t_0 indicate pressure and temperature at the surface of the earth (2); $p_{2.5}$ and $t_{2.5}$, the same at 2.5 km. elevation; p_7 and t_7, the same at 7 km. elevation; p_h and t_h, the same under the limit of the stratosphere; while h and t represent respectively the height of the stratosphere and its temperature. No absolute values are given, merely the departures from mean values. The continuous curves represent values of pressure and of h respectively, the dotted curves represent temperature values; where a curve runs above its mean line the value is above the mean, etc. The curves are drawn over a high-pressure region and the two low pressure regions lying at the sides of the same. On the abscissas H indicates region of pressure rise and L indicates region of pressure fall; the annexed small letters indicate as follows: r for rear side, c for center, f for front side of H and L respectively.

There is noted in this figure a characteristic shifting of phase as between pressure and temperature curves which enters into many of the earlier conceptions of the structure of high depressions and anticyclones. Ficker (3) recently occupied himself with the matter when he explained the "compound" depression. In regard to these questions Schedler's results now appear to me to be quite interesting, even if, to be sure, merely a scheme is obtained which still may require substantiation by direct coordination of pressure and temperature values at the several phases in the pressure formations in order to be relied upon fully. Yet, despite this uncertainty I believe that the scheme hits upon the reality of the structure the ground for such belief being the agreement with the Dines' factors and with the scheme of a high depression previously constructed by myself. (4)

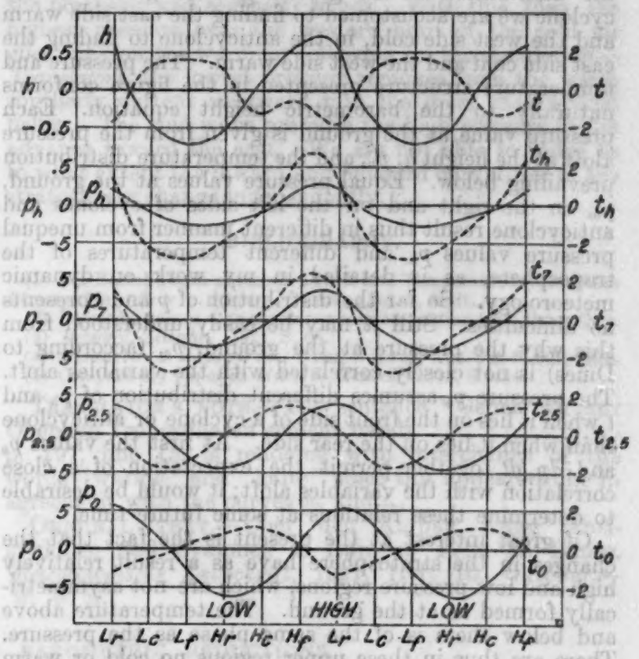

FIG. 1.—Temperature of the stratosphere, the height of its base, and pressures and temperatures at various levels in the troposphere.

For the understanding of the structure let us proceed from above—from the stratosphere. Here we see (in the two upper curves) high position of the stratosphere coincide with low temperature without any shifting of phase, and below, under the stratosphere, we see the pressure p_h with exactly the same course as h. Here the conditions are simple in the highest degree; when the cold stratospheric air lies high the pressure below it is high, and conversely. While over Europe at 10 to 12 km. elevation the west wind prevails we have really a pressure gradient toward north; the isobars run from west to east. They are at one place bent toward the South (lower pressure, p_h), next they are bent toward the North (higher pressure, p_h). Over the former place the stratosphere is warm, over the latter it is cold. If we descend into the uppermost tropospheric stratum we find there cold air in the low pressure region and warm air in the high pressure region (see note by translator), thus a contrast relative to the stratosphere; moreover the curve t_h already shows a slight shifting of phase to the West relative to p_h.

At 7 km. elevation the curve p_7 is slightly shifted in phase toward the east relative to the upper curves, at

2.5 km. elevation there is still more shift and at the ground the pressure extreme is found about one-eighth of the wave length farther to the east than the extreme of p_h. With downward advance the temperature curves undergo opposite shifting. The extremes lie farther and farther to the west. At 2.5 km. elevation the rear side of the anticyclone is warm, the front side is cold; at the ground almost the entire anticyclone is cold, but this conforms indeed to the temperature inversion near the surface of the earth on the fair mornings when flights were made, and which need not concern us too much. The distribution at 2.5 km. elevation much better represents the general conditions in the lower strata than does the distribution at the ground as here given. In the cyclone we are accustomed to finding the east side warm and the west side cold, in the anticyclone to finding the east side cold and the west side warm. The pressure and temperature structure presented in the figure conforms naturally to the barometric height equation. Each pressure value at the ground is given from the pressure aloft at the height h, p_h, and the temperature distribution prevailing below. Equal pressure values at the ground, p_0, on the right and on the left sides of cyclones and anticyclone result thus in different manner from unequal pressure values p_h and different temperatures of the troposphere, as is detailed in my work on dynamic meteorology. So far the distribution of p and t presents no difficulties. Still it may be easily understood from this why the pressure at the ground, p_0, (according to Dines) is not closely correlated with the variables aloft. The pressure p_0 assumes different distribution of p_h and t when it lies on the front side of a cyclone or anticyclone than when it lies on the rear side. At first the values p_0 and dp_0/dt together permit the expectation of a close correlation with the variables aloft; it would be desirable to determine these relations at some future time.

Of great interest at the present is the fact that the changes in the stratosphere have as a result relatively high and low-pressure regions, which are not asymmetrically formed as at the ground. The temperature above and below them is of the same phase as the pressure. There are thus in these upper regions no cold or warm front or rear sides. In the stratosphere the minimum is a whole is warm, the maximum as a whole is cold.

How is this difference relative to the pressure regions at the ground explained? The asymmetry in temperature near the surface of the earth arises from the fact that the air flows into the minimum from different latitudes. If the winds at the ground should blow parallel to the isobars then there would be no temperature asymmetry, they would circulate around regions of high and low pressure. Aloft the winds blow from west to east; the inward and outward curvatures of the isobars are followed by the stream lines; the northerly stream lines are warmer than the southerly ones so that curvature toward the south is filled by air generally warmer. We have reached the upper limit of the thermal structure of the atmosphere, the pressure distribution is primarily an effect of the polar whirl (gradient toward the Pole) and secondarily modified by changing temperature with streamline oscillation.

What Ficker calls the "primary" or upper depression is essentially different from the familiar lower one and it much simpler. The phenomenon of asymmetry first appears below the upper depression and develops slowly down to the ground. In the troposphere there gradually form, from indentation of the west-east isobars by higher temperature at the south, closed isobars with the wind system belonging thereto—cold north winds and warm south winds. The low temperature of the north winds produces the shifting of the phases of the pressure curves to the east as the surface of the earth is approached.

The developed high cyclone or anticyclone became most easily understood when we proceeded from conditions in the stratosphere. An explanation as to origin in this way is not contemplated; there exists, on the contrary, no reason to assume that the phenomenon, has its point of origin aloft. If there is conceived at the earth's surface anywhere an inrush of cold air from the north, and if the same continues long, then the north wind and also the south wind completing the exchange of air will gradually invade the higher strata until even the stratosphere is drawn into the meridional shifting. Then there is obtained exactly the temperature distribution that is presented in the figure; cold under warm, warm under cold.

In their compilation of the international balloon ascents Wagner and Gold have calculated the mean values of temperature for the different regions of Europe, from which may readily be found the temperature gradients which are of importance in a horizontal shifting. The following table gives such temperature differences in the annual mean:

TABLE I.

	South minus North Europe (Wagner).	Milan, Pavia minus England, Hamburg, Paris, Nede (Gold).	Milan, Pavia minus Pavlovsk (Gold).	Milan, Pavia minus Berlin (Gold).	England minus Pavlovsk (Gold).
Earth	5.9	3.4	9.7	4.5	7.3
1 km	6.2	2.8	9.7	3.9	6.9
2 km	4.6	1.7	8.4	3.4	6.6
3 km	3.9	0.9	7.9	2.3	6.6
4 km	3.7	0.4	7.2	1.9	6.2
5 km	4.2	0.2	6.4	1.4	5.6
6 km	4.5	0.1	6.1	1.5	5.2
7 km	5.0	−1.2	4.1	0.4	4.2
8 km	3.9	−0.9	4.6	1.1	4.7
9 km	2.9	−1.5	2.9	0.5	4.1
10km	1.5	−0.1	1.4	0.8	2.1
11 km	−0.5	−1.0	−1.5	−0.7	0.1
12 km	−2.0	−2.3	−4.6	−2.1	−1.2
13 km	−2.4	−2.5	−7.0	−2.8	−3.9
14 km	−2.2	−1.0	−5.8	−1.0	−4.2
15 km	−1.4	−2.1	−6.0	−0.8	−3.1
16 km	−0.2	−0.8	−6.1	1.3	−4.8

The series of values for these differences harmonize entirely with the scheme of the figure. Since on the front side of the depression and on the rear side of the anticyclone warm south wind is found, it would then be indeed very unnatural to assume that the upper cold (of the stratosphere—*Translator*) over these regions does not come from southern latitudes, thus unnatural to assume that the oscillations of the stratospheric temperature are not caused by shiftings of the stratosphere in horizontal direction. (5.)

Thereby the structure of the high cyclones and of the high anticyclones appears to be made considerably clearer. The high anticyclone forms from a south current, which is warm below and extends up to the stratosphere, where it brings cold; at the beginning (at the ground—*Translator*) the pressure is highest on its front side corresponding to the gradient of the south current.

In the middle strata through out-swelling toward the north of the stratosphere, which is colder toward the south, the high temperature of the south current coincides with high pressure; in the lower strata there arises on the east side of this high pressure a countercurrent from the north which shifts the temperature maximum to the west and the pressure maximum to the east, and thus brings about the phase difference between pressure and temperature distribution. On the other hand, the high cyclone arises from a north current, cold below and warm above; aloft the lowest pressure falls under the lowest position of the stratosphere. On its front side there develops in the lower levels a warm countercurrent which shifts the pressure minimum toward the east and the temperature minimum toward the west. The "tie" between upper and lower pressure formations is fully accounted for from this. It is a matter of only one depression which has phase shiftings, locally possibly different, but it is not a matter of two depressions, an upper and a lower, as Ficker supposed. The high pressure above is characterized by the fact that it is as a whole cold, the low pressure by the fact that it is as a whole warm. The thermal explanation of the phenomena is practicable when it is borne in mind that for dynamic reasons the isobars run from west to east, that thus at the north there lies really a lesser mass above the given high level than there lies at the south. In this way the south current brings rise in pressure aloft, while the north current brings fall in pressure.

The fact that over a region with 1,000 to 2,000 kilometers radius, and up to several kilometers elevation, the air can be warm and can meanwhile move downward, the fact of the stationary anticyclone, warm below, may be explained, so far as I see, not otherwise than by a south current in the substratosphere, whose cold air sinks at the north in warmer regions and meanwhile forces down the lower, dynamically heated air. This anticyclone has thus certain similarity to a waterfall, the center of gravity of the entire mass descends despite the descent of warm air. We have a circulation in which the energy is furnished by the cold substratospheric air of the Tropics and the sub-Tropics.

The terms "north" and "south" are used here representatively. Taken exactly it is a matter of the position of the stratosphere relative to the season; in Europe, as is evident from the above table, the oceanic west (England) stands in similar contrast to continental Russia as normally the south stands to the north.

In the building of high cyclone and anticyclone from a lower formation the cold mass of air forcing its way at the ground is evidently the bearer of high pressure until the higher air strata of the stratosphere are drawn into the northerly and southerly winds. With this, then, the highest pressure over the western limit of the cold air goes out over the warm air following (in the circulation—*Translator*), the lowest pressure removes from the warm southerly current westward into the mass that is cold below. The cold wave precedes the high pressure in the advance toward the east. We are not able to judge as to what extent the inward and outward curvatures of the stratosphere change independently.

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(1) Die Beziehungen zwischen Druck und Temperatur in der freien Atmosphäre. *Beitr. z. Phys. d. fr. Atm.*, Bd. 9, Heft. 4.
(2) I owe the values t_o to courteous communication from the author.
(3) *Meteorol. Zeitschr.* 1921, S. 65.
(4) *Sitzungber. d. Akad. Wiss.*, Wien, Bd. 119, Abt. 2 a, S. 697, 1910.
(5) Compare my paper in *Meteorol. Zeitschr.* 1913, S. 434.

TRANSLATOR'S NOTE.—The sentence "Gehen wir zur Obersten Tropospharen schicht herab, ... p. 297, line 15, is rendered with interchange of the words "warme" and "kalte" since this appears to be in agreement with the curves p_h and t_h.

ORIGINAL TEXT.—Über den Aufbau hoher Antizyklonen und Zyklonen in Europa. Felix M. Exner. *Meteorologische Zeitschrift*, 1921, Heft 10, Oktober.—*W. W. R.*

THE TORONTO SYMPOSIUM ON BAROMETRIC REDUCTIONS.

By C. LEROY MEISINGER.
[Weather Bureau, Washington, D. C., Jan. 10, 1922.]

A suggestion made at the Chicago meeting of the American Meteorological Society in 1920 developed, at Toronto, into a satisfactory symposium on the reduction of barometric pressure in the United States and Canada. This symposium should not be regarded as a culmination of effort, but rather as a significant step toward a goal, the road to which is beset with many pitfalls and obstacles. But there is little doubt, it is believed, that this symposium does signify much for the future of American barometry. For 20 years, the United States, Canada, and the West Indies have used the system of barometry devised by Bigelow. This system was, without question, a thorough and capable treatment of one of the knottiest problems of practical meteorology; but it was not exhaustive—even in the mind of Bigelow the work was not finished—revisions and reexaminations of the gradients, methods, and errors, should follow after a few years of taking homogeneous observations. But these 20 years have passed. Those most familiar with the reductions are well aware of the fact that they are not the best; at the same time, improvement of Bigelow's treatment is regarded as most difficult. The Toronto symposium was born of this consciousness of the difficulties of reduction. Whether this symposium will result finally in an improved system of reductions depends upon how thoroughly and searchingly the problem is studied, and how practical and workable are the suggestions offered by investigators.

In order that those who did not have the opportunity of attending the Toronto meeting may be informed of this interesting session, it is believed that a brief résumé of the several papers, in the order of their presentation, may be of value.

The nature of the problem from the practical standpoint was stated in a short communication from Prof. C. F. Marvin, Chief of the United States Weather Bureau. He said, in part:

> It is well known that, strictly speaking, a reduction to sea-level of continental observations is wholly a visionary and hypothetical thing, since to effect the reduction we must necessarily assume that an atmosphere exists below the station whose observations are to be reduced. We assign to this atmosphere a given temperature and moisture content, density, etc., and our reduction depends upon these assumptions. Since the intervening atmosphere has no existence our assumptions are necessarily fictions, and the final result of the so-called reduction to sea-level has in reality no meaning.

He then explained how, by so treating the temperature argument and the other assumptions that they will satisfy the requirements for smooth isobars on the daily

weather map, the forecaster is enabled to forecast weather even upon the basis of appearances on this assumed sea-level. Attempts to remedy these difficulties, which are especially acute in the plateau regions of the west, have led to the suggestion that maps of free-air levels would be a possible panacea. But such maps, feared Prof. Marvin, would require the training of a new school of forecasters, owing to the fact that upper-air maps would bear a different relation to surface weather from that of the present sea-level maps. He concluded that:

> It appears very problematical if a change in present practices of reducing barometric pressures as represented by the reduction tables used by the Weather Bureau, or others that are appreciably equivalent thereto, will prove of value. However, the academic study and examination of the problem is one of the very greatest interest and should be pursued in an effort to minimize what appear to be the unavoidable errors and fallacies involved in present systems.

The last sentence of Prof. Marvin's remarks, it seems to the writer, constituted a very acceptable keynote for the symposium. Moreover, the burden of his remarks indicates that, in the academic study of the question, the element of practicality must not be forgotten. While it is easy and often desirable for the scientific investigator to disencumber himself of the practical aspects of the problem, it seems (and the history of American barometry proves that this is true) that in a study of this character the investigator must constantly project his studies against a background of practicality. One must take care that one's suggestions are practical, else the labor expended on the problem may bear no greater fruit than a spreading of printer's ink.

The writer contributed two papers to the discussion, the first of historical character, and the second suggesting the possibilities of upper-air maps. The first paper entitled "The history of barometry in the United States," covered the salient features of each of the several methods of pressure reduction that have been employed in the United States since the beginning of the Signal Service, namely, the Guyot tables, the Abbe-Upton monthly constants, the Ferrel tables, the Hazen reductions, and the Bigelow tables at present in use. These various methods are too complex for hasty review here, but it is hoped that the extended paper may be published within a few months. From the several methods, attention was drawn to three features that were common to them all: (1) All methods reduce to sea level; is this the most suitable level? (2) All methods have their weakness in the assumption of a hypothetical atmosphere below the station and in the treatment of its temperature; is Bigelow's treatment of the temperature argument, which is admittedly complex, the most satisfactory, and might we not improve upon it in sea-level reductions after acquiring so many years of homogeneous records, and much aerological information that Bigelow did not have? (3) All workers found peculiar pressure discrepancies, left unexplained by Bigelow, which he said should be given further study; are these discrepancies real, or will not a reexamination of station records possibly either eliminate them, or lead us to their cause and an understanding of their nature? Heretofore, they have been buried or concealed behind corrections, but never explained. From these considerations, it appears that, regardless of the advisability of introducing other reduction levels than sea level, a new study of pressure data and a reexamination of them would probably lead to better reductions to sea level.

The second paper discussed the results of continued research upon the possibilities of drawing accurate pressure maps at the levels of 1 and 2 kilometers above sea level. The central assumption or keystone of this work is that surface-wind directions—assuming, of course, an open and free anemometer exposure—are reliable indices of conditions of temperature, hence pressure, aloft. A study of all available kite data in eastern United States abundantly justifies this assumption, and it is confirmed in recent statistical data summarized by the Aerological Division of the Weather Bureau showing the average seasonal deviations of wind with altitude from surface direction and the percentage frequency of clockwise and counterclockwise turning.

Two papers were read by title, owing to the absence of the authors, the first by Prof. Alexander McAdie, and the second by Mr. W. G. Reed. The first on "Sea level *vs.* the megadyne base," recommended the practice of reducing to standard bases, differing according to station elevation. The author said: "* * * thus, if a station is approximately 100 meters above sea level, the base is 1,000 kilobars; if the elevation is 1,000 meters, the base would be 900 kilobars; at 10,000 meters, 300 kilobars." The second on "Major wind streams *vs.* high-and-low-pressure centers as the basis for weather forecasting" contained matter of interest, part of which was touched on in the discussion. Mr. Reed contended, and probably rightly, that the true sources of our weather changes are the interrelations of the great streams of air, each with its peculiar and characteristic temperature, moisture, and rate of movement. He believes that our scheme of following day to day pressure changes is only an indirect method of getting at those streams of moving air. He said:

> It is my belief that we are really concerned with moving air and the systems of air streams. If this is the case, we should map air movement rather than air pressure. Our maps should show the positions, directions of flow, and speeds of air streams, together with any changes in direction and speeds. These figures, rather than pressures, may be the most important facts to be presented as showing cyclonic conditions. I realize, of course, that we have built up in the past half century a system of handling air pressures which may readily be mapped, and which possibly may give us indirectly the same information as we should get directly by mapping air streams. Furthermore, the technique of mapping air movement is as yet only partly developed.
>
> However, I believe the place of air pressure in meteorology should be reconsidered. This element doubtless has a historical value and is of great importance in empirical forecasting; its place in a rational system of forecasting based upon the physics and dynamics of the atmosphere is not so clear. Undoubtedly pressure is easier to observe than air movement, especially upper air movement in cloudy weather. For this reason, at least it is probable that the observation of pressure should be continued to provide a foundation for interpolation to supply gaps in data for air movement obtained by direct observation, if for no other reason.

Thus, it appears that Mr. Reed in preparing his paper, realized what Maj. W. R. Blair, in a written discussion said, namely, that he doubts whether "weather services will be able to come to it in practice, even though they appreciate its validity." It might be suggested that the element of practicality, mentioned earlier in this discussion, is the pitfall toward which this suggestion leads; it is undoubtedly true that an adequately developed method for charting the great air streams would be of untold value, but how can it be done? No one can say that future development may not be in that direction; but, at present, with our loose-meshed network of aerological stations, it can not be seen wherein this offers a helping hand to the limping plateau reductions.

Mr. Reed next brought up the question of departures from station normal as a possible substitute for sea-level reduction. This question was also raised in the discussion by Dr. J. Patterson, who said that in India, the practice of sea-level reduction applied only to stations of less than 3,000 feet altitude, and that above that level, departures from station normal were used with success. Dr. Humphreys said that while this suggestion was so old that it was difficult to say who first proposed it, so far as he knew, no thorough examination of its merits or faults has been made, and he suggested that such an examination be made. Dr. C. F. Brooks urged the criticism that horizontal differences of normal pressure might introduce the conception of erroneous gradients when departures are plotted. He cited the case of the Azores HIGH and the Iceland LOW and showed how a negative departure of pressure at the Azores and a positive departure at Iceland might obtain and still the Azores pressure be higher than that at Iceland. Of course, this was an extreme case and, owing to lesser geographical distances, might lose some of its force. He showed, however, that maps of departures from normal could be used in connection with maps of normal distribution and departures from the normal gradient winds computed. These computed departure of winds would be of significance relative to departures in temperature. Thus, a wind which was more northerly than usual would in the United States, ordinarily indicate the existence of, or the tendency toward, a negative departure in temperature. Another consideration concerning this question was that of cases where stations of considerably different altitude might be quite close together. It is known that when on account of cold weather the pressure is high at the surface a LOW is found aloft; this might cause positive departures at the lower station with negative departures at the upper station, an altitude effect entirely. This might introduce difficulties where the plateau and Great Plains meet. Dr. Patterson admitted the validity of these considerations, but said that his experience in India had not indicated that such difficulties were serious. At any rate, an investigation of this problem would be most attractive and offer opportunity for some good work.

Prof. H. J. Cox, of the Chicago office of the Weather Bureau, stated that, from the forecasters' point of view, some improvement in plateau barometry would be eminently desirable. He cited the situation that obtains when a HIGH is situated in the northern plateau and a LOW to the southwest. The northeast-southwest gradient as shown on the sea-level map is then so steep that if the winds were blowing with a force indicated by the closeness of the isobars "they would blow the mountains away." Such gradients are nothing if not misleading. The forecaster may be able to make proper allowance for them, but the student, as Dr. Humphreys pointed out, is helpless and confused when confronted by such a situation. Assuming that such a gradient would obtain at sea-level if the continent were removed, we have yet to inquire *of what value is this fact in actual forecasting?*

The symposium was closed by a paper by Dr. Brooks on the use of clouds in local forecasting, explaining how satisfactory temperature forecasts for Worcester, Mass., had been made on the basis of upper-air maps, deduced from cloud movements.

In order that the substance of the several papers and the opinions expressed in the discussion might be given some tangible form, a resolution was drawn up and adopted at the afternoon meeting of the following day. The unofficial character of the symposium and the views expressed were recognized in the resolution. Its purpose was rather to stimulate the several weather services concerned to investigational activity than dogmatically to express an opinion. This resolution follows:

Whereas the reduction of barometric pressure to sea level, as practiced in the United States and Canada, is generally conceded to be unsatisfactory under extreme weather conditions, especially in the plateau region of the west; and,

Whereas the sea-level reductions afford an unsatisfactory basis for the forecasting of upper winds for the benefit of aviation; and,

Whereas a careful study of the method of reductions at present employed, devised by Bigelow 20 years ago, reveals that he recognized the necessity for a reexamination of barometric data after such time as all stations might have long homogeneous records; and,

Whereas all students of the barometry problem, including Bigelow, have encountered anomalies or discrepancies at certain stations, manifested by the failure of such stations to conform to the distribution of pressure in their vicinity, and since no satisfactory scientific explanation of the i rregularities has been advanced: Therefore be it

Resolved by the American Meteorological Society, assembled at Toronto, Canada, this 29th day of December, 1921:

1. That the time is now opportune for a reexamination of the barometric methods employed in the United States and Canada with a view to the possible improvements of pressure reductions.

2. That such investigations should include an examination of—

(*a*) The accuracy of maps of the free-air, and their value as aids to forecasting for aviation and general forecasting of weather.

(*b*) The value and practicability of construction daily charts of the departure of station pressure from normal as aids to forecasting in the plateau region of the west.

(*c*) The validity of Bigelow's temperature argument which is included in station reduction tables at present in use.

(*d*) The nature and cause of the barometric discrepancies noted above and their true values.

3. That a copy of these resolutions be forwarded to the chiefs of the Weather Services of the United States, Canada, and Mexico, inviting their attention to the considerations herein, and urging that they give these matters their earnest consideration at the earliest practicable time.

SUMMARY OF THE HURRICANES OF 1919, 1920, AND 1921.

By WILFRED P. DAY.

[Weather Bureau, Washington, D. C., December, 1921.]

Of the storms of tropical origin occurring during 1919, 1920, and 1921, ten have been classed as hurricanes. These storms exhibit some of the variations from type, and also show great divergence in their paths from the average tracks of these disturbances. They bring out a strong relation between the positions and the movements of areas of high barometer and their own subsequent paths. These storms have been fully described in previous issues of the REVIEW, but their importance entitles them to a brief summary. Figure 1 shows the tracks of these hurricanes and another storm of tropical origin which may have been an incipient hurricane.

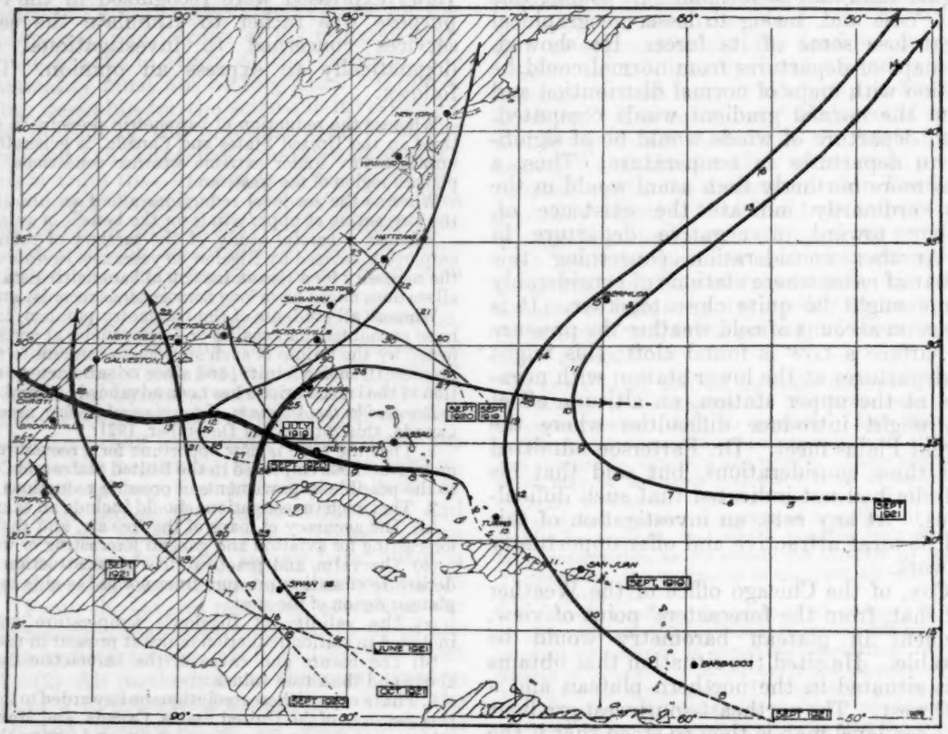


Fig. 1.—Tracks of the centers of tropical storms during the hurricane seasons of 1919, 1920, and 1921 with approximate locations at 8 a. m. (75th meridian time) for the duration of each storm.

Storm of July 2–4, 1919.—This storm developed over the eastern Gulf of Mexico on the 2d, was at all times of very small diameter, but with isobars exhibiting the vortex core of the true hurricane. The eastward movement of a trough of low pressure opened up a path and the storm fell into its wake, striking the coast a short distance east of Pensacola, Fla. Some damage was done but storm winds were of short duration.

Storm of September 3–14, 1919.—Some indications of a tropical disturbance were noted as early as the evening of the 2d in the vicinity of the island of St. Kitts (in the Leeward group). This LOW moved slowly (and apparently with no further development) in a northwesterly direction, starting its recurve on the 4th into the southern opening of a shallow trough. It was now in the vicinity of Turks Island, but meanwhile the trough was filling up, and with high and rising pressure to the north the disturbance was brought to a standstill. It was here on the 6th that the characteristics of a hurricane began to develop; and with the increasing weight of the HIGH to the north the storm was propelled slowly in a new course toward the west, at the same time gaining great intensity. The path followed the southern periphery of the HIGH, which was now nearly stationary, passing over the Florida Keys on the 10th and starting to recurve over the eastern Gulf of Mexico on the 11th. But again the circulation was not strong enough to complete the recurve, and a rapidly advancing HIGH from the northwest reversed the air movement before the hurricane had reached the turning point. Under these new conditions the storm after apparently remaining stationary for about 12 hours, now (the evening of the 12th) began, at first slowly and then with increasing speed of progression, a new path toward the west, which carried it to the Texas coast during the afternoon of the 14th. The center struck near Corpus Christi, the hurricane being one of the most severe ever recorded. The day to day changes in the general circulation and their effect upon the subsequent path of the storm are more clearly shown than usual on account of the very slow rate of progression and the fairly complete observations which have since been accumulated.

Storm of September 29–October 1, 1919.—This was a tropical disturbance which developed and moved nearly westward along the southern edge of a belt of high pressure, passing inland south of Savannah, Ga., but lacked the energy of a hurricane.

Storm of September 17–22, 1920.—This storm developed in the vicinity of the Swan Islands, moved north-northwestward with increasing intensity, but retaining its small diameter. It was prevented from making a normal recurve by high pressure to the northeast, and the increasing effect of this HIGH as it spread out toward the southwest caused a further shift of the storm's course toward the northwest. It passed inland on the Louisiana coast, where winds of hurricane force were reported, particularly on the right-hand side, where the isobaric gradients were increased by the proximity of the HIGH.

Storm of September 20–23, 1920.—This storm, which was nearly coincident with the preceding, developed off the South Atlantic coast in an area of low barometer which had stagnated there. No low barometer readings were recorded at Weather Bureau stations in the vicinity because of the extremely small diameter of the storm, but the lightship off Smiths Island, N. C., was dragged several miles from its station and a 72-mile wind was reported.

Storm of September 26–30, 1920.—The first evidences of this disturbance were noted on the morning of the 26th over the eastern Gulf of Mexico. Under the influence of a ridge of high pressure it was propelled slowly westward. On the 28th it came under the influence of a rapidly developing trough of low pressure, recurved, and moved rapidly northeast. But in crossing Florida it lost its identity as a hurricane, and on the morning of the 30th could not be separately identified in the general trough formation which covered the Atlantic coast region. This large and elongated disturbance developed into a severe coast storm, which should not, however, be confused with the original hurricane. In fact, there is some doubt whether the Gulf disturbance was ever a true hurricane. The heavy north winds which occurred over the Gulf on the 30th, long after the passage of the storm center, were due to the steep-pressure gradient formed as a great HIGH moved down from the northwest in the rear of the trough.

Storm of June 14–23, 1921.—This storm apparently developed over the western Caribbean Sea about the 14th and was carried northwestward by the general circulation, pressure being high over the eastern Gulf of Mexico and low over Mexico. This distribution of pressure continued until the 19th, the disturbance meanwhile crossing the Gulf of Honduras, the Yucatan Peninsula, and passing into the Gulf of Campeche. So far, heavy winds had occurred only on the right-hand side of the storm path, in the direction of the normal increase in pressure. No further reports from the vicinity of the storm were received until the late afternoon of the 21st, when special observations indicated its position some-distance off the Rio Grande, and later reports showed a north-northwest movement and a fully developed hurricane. The storm center crossed the Texas coast line at Matagorda Bay and moved nearly due north over Palacios, Wharton, and Wallis, Tex., the last-named place being about 40 miles west of Houston, Tex., the nearest approach to a regular Weather Bureau station.

The three tropical storms during the period September 5–15, 1921.—From more complete reports which have since accumulated it appears that three important tropical storms were coexistent over southern waters during this period. A small disturbance made its appearance over the southwestern Gulf of Mexico on the 6th and passed inland near Tampico, Mex. The northward movement of the disturbance was evidenced by the torrential rains which fell over southern and central Texas between the 8th and 10th.

On the morning of the 8th a small but very severe hurricane made its appearance to the southeast of Barbados, crossed the Grenadines, moving northwest and with low pressure to the northward the storm turned in that direction, passed through the Mona Passage, and to the east of Turks Island during the 10th and 11th and crossed the Bermudas on the 15th with undiminished intensity.

On the 12th, when the preceding storm was central immediately northeast of Turks Island, the S. S. *Capillo* reported a hurricane of small diameter a short distance southeast of Bermuda. This storm has since been traced back (Tropical Hurricane of Sept. 5–15, 1921, by F. G. Tingley, in this issue, p. 674) and was found to be in existence as early as the 5th in approximate Lat. 22° N. and Long. 54° W. As shown by the accompanying chart, the storm moved slowly west-northwest, recurving near Lat. 27° N., Long. 67° W. These two storms attained great severity over the steamer lanes as they passed into higher latitudes.

Storm of October 20–28, 1921.—This was probably the most severe hurricane since the September storm of 1919. A disturbed condition was first noted to the southwest of Jamaica about the 20th. Then followed a very rapid development in area and intensity. Carried along slowly in the general circulation it passed near the Swan Islands, through the Yucatan Channel, and during the 24th, with high pressure breaking down in front and under the influence of a southwest current in the upper air, the hurricane recurved and on the morning of the 25th was centered immediately southwest of Tampa, Fla. A clear path was now apparently open to the northeast, but, meanwhile, a great HIGH was bearing down from the north and under its influence the storm, which had lost considerable intensity while crossing Florida, was forced to take a new path to the east-southeast and was last noted on the 28th south of Bermuda and still in the latitude of Tampa. Some very low barometric readings were made in the path of this hurricane, the schooner *Virginia* reporting 27.84 inches in the Yucatan Channel on the 23d, the S. S. *El Estero*, 27.84 inches at 10 p. m. of the 24th in the eastern Gulf and 28.12 inches at Tarpon Springs, Fla., at noon on the 25th.

HAILSTORM IN ALABAMA, NOVEMBER 14, 1921.[1]

By P. H. SMYTHE, Meteorologist

[Weather Bureau, Montgomery, Ala., Jan. 7, 1922.]

The weather map on the morning of November 14, 1921, showed a slight barometric depression centered in extreme northeastern Texas, with a pressure gradient of about three-tenths of an inch from the center of the LOW to the south Atlantic coast. North of the LOW, pressure was only relatively high, with no well-defined crest. During the day the northeast-Texas depression filled considerably and the center of the high lying to the north drifted eastward to Missouri. The evening weather map on November 14, showed pressure to be nearly uniform east of the Rocky Mountains, with isotherms running almost east and west from the Rocky Mountains to the Alleghenies, and varying from freezing in the northern portions of Illinois, Indiana and Ohio, to 70° to 74° on the central and east Gulf coast. During the night of November 14, the HIGH increased somewhat in intensity

[1] See also Mo. Weather Rev., Sept. 1915, 43: 446-448 Fassig, O. L.: Remarkable fall of hail in Maryland. (Illustrated.)

became better defined, and centered in Indiana on the morning of November 15, while pressure in the Gulf and South Atlantic States also increased somewhat. The weather map on the morning of November 14th indicated conditions favorable for local thunderstorms in this section, and forecast was made accordingly. During the afternoon of November 14, thunderstorms, attended by light to heavy hail occurred in a strip of territory extending from Pickens County, Ala., southeastward across the State to Barbour County, Ala. The hailstones ranged from about the size of buckshot to as large as a baseball, the largest weighing as much as a pound. In the area mentioned the maximum temperatures for the day ranged between 73 and 83.

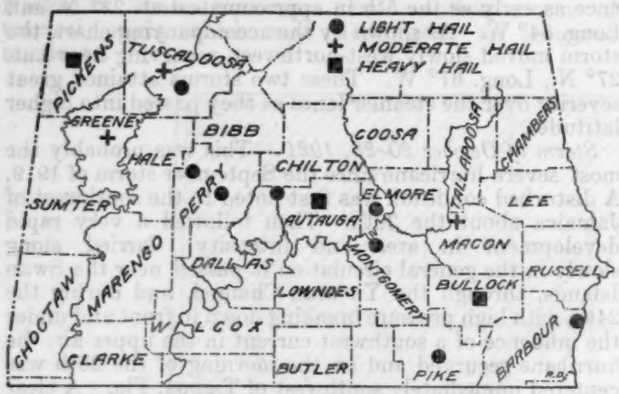


FIG. 1.—Portion of Alabama showing occurrence of hail-storms.

Material damage was done by the hailstones to paper roofing, windows, skylights, etc., and some poultry and live stock were killed, and a few persons slightly to badly injured. The damage was greatest in the vicinity of Reform, Pickens County; Vida, Autauga County, and Union Springs, Bullock County.

The following are extracts from a few of the reports received from correspondents:

Reform, Pickens County, Ala.—Montgomery (Ala.) Journal, Associated Press. Hailstones as large as baseballs and weighing a pound each in some instances, fell here late in the afternoon of the 14th. Damage estimated at $5,000 was done in this vicinity. In the mill village composition roofing was torn off houses and occupants in some instances had to move out. Thirty-two windows were broken out of the county high school.

Reform, Pickens County, Ala.—S. K. Dorroh's report: All the paper roofing in town is being repaired. A lot of the hailstones were as large as hen eggs.

Eutaw, Green County, Ala.—Correspondent's report: Three separate storms of hail about half hour apart; continuous rain from 2:30 p. m. to 4:30 p. m. Hail fell about 10 minutes each time. No damage except to roofing.

Tuscaloosa, Tuscaloosa County, Ala.—Mrs. Kate T. Willingham's report: Hailstorm came from northeast. Hail about the size of partridge eggs, approximately lasted 20 minutes. After a cessation of about 15 minutes stones came from due north, with hail stones as large as hen's eggs, largest weighing one fourth pound. After cessation of about 10 minutes storm came from northwest, with hail smaller than second storm and not so intense, but wind much stronger than other two storms. No damage except to glass.

Prattville, Autauga County, Ala.—Report to Montgomery Journal: The stones were so large and heavy glass windows were reported broken and limbs of trees were cut off. It was declared to be the most extraordinary hail in size ever seen here.

Mountain Creek, Chilton County, Ala.—Mr. J. T. Culpepper's report: Hail in balls, size from buckshot to larger than goose eggs, some weighing 1 pound or more. Gardens were damaged; also slight damage to fruit and other trees, and some stock slightly injured by hail.

Milstead, Macon County, Ala.—Mr. W. U. Wall's report: On November 14 Milstead was visited by a heavy hailstorm in which there were stones as large as hen's eggs; paper roofing was damaged, and in some instances window glass broken. Approximate amount of damage, $500.

Union Springs, Bullock County, Ala.—Mr. R. W. West's report: The writer viewed the unusual condition from the northeast, and indications pointed to extraordinary atmospheric conditions and without doubt an unusual windstorm, which may have reached proportions of a tornado. Others viewed very much the same conditions in southwest. Wind was not very strong, except at apparently a high altitude. The hailstones covered the ground, and were from 4 inches to 8 inches in circumference. The principal damage was to composition roofs, skylights, and window panes, all of which was done by hailstones.

Union Springs, Bullock County, Ala.—Mr. S. P. Rainer's report: It thundered, with lightning, all night. Some stock was killed. The ground was covered with hailstones. The stones were from 1 inch to 8 inches in circumference. It was the worst hailstorm I ever saw.

Union Springs, Bullock County, Ala.—Mr. P. L. Cowan's report: Very heavy hailstorm at 6:30 p. m., November 14. The largest hailstones measured 7 inches in circumference. The gross damage in this community from hail, rain, and wind will amount to about $600 or $800.

Vida and White City, Autauga County, Ala.—Report of Mr. Claude B. Smith, Prattville, Ala.: The storm occurred about 5:00 p. m., November 14. The hail was extraordinary; one stone weighed 7 ounces. No material damage was done to property, except a few minor roofs were blown off and damaged by hailstones. Some live stock and poultry were injured.

Montgomery, Montgomery County, Ala.—Weather Bureau: Thunder was heard at Montgomery at 4:20 p. m. and again at 9:45 p. m. Rain began at 5:42 p. m. and continued at intervals until after midnight; 2.69 inches of rain fell from 5:42 p. m. to 11:00 p. m. Hail fell from 6:00 p. m. to 6:04 p. m., and again from 10:10 p. m. to 10:15 p. m. The hailstones in both instances were about the size of peas. No damage was done and hail melted soon after it fell.

The thunder and hail conditions began in the northwestern portion of the area between 2:00 p. m. and 4:00 p. m., and extended to the southeastern portion by 7:00 p. m., November 14.

GREAT RAINSTORM AT MOUNT WILSON, CALIF., DEC. 17-21, 1921.

By WENDELL P. HOGE, Special Observer

[Mt. Wilson, Calif., Jan. 10, 1922.]

The biggest rainstorm that has occurred at Mount Wilson, Calif. (elevation 5,704 feet) since rainfall observations were begun nearly 18 years ago, was recorded during the latter part of December 1921. Rain began falling at 6:40 p. m. December 17 and continued with but one interruption of 60 minutes, until 8:40 a. m. December 21, giving a total precipitation for the period of 21.88 inches. Beginning again at 2:00 a. m., the 22d, 1.15 inches was recorded up to noon the 23d.

What was apparently a second storm began with snow about 2:00 a. m. the 25th, turned to rain shortly after and continued without interruption until 4:40 p. m. the 27th, adding 6.35 inches, making a grand total for the 9 days and 22 hours of 29.38 inches.

The heaviest continuous downpour occurred from 3:00 a. m. to 3:00 p. m. the 19th, during which time 8.50 inches was recorded. The greatest amount for 1 hour was 1.25 inches, 9:10 to 10:10 a. m. the 19th. At 8:45 a. m. the 19th rain fell for 8 minutes at the rate of 2.40 inches per hour.

A standard 8-inch rain-gauge collector rests on the roof of a low one-story building, which is located within a few feet of the summit of the mountain, and near the edge of a very steep slope running off toward the south. A copper pipe leads from the collector down to a Marvin automatic recorder in the room below. A 16-candle electric lamp is placed under the collector on the roof, and the current turned on when snow falls. This gives enough heat to melt the snow, thus making a continuous record. Four and one-half inches of snow fell during the storm, which was all melted from the ground before the rain ceased.

(To face p. 660.)

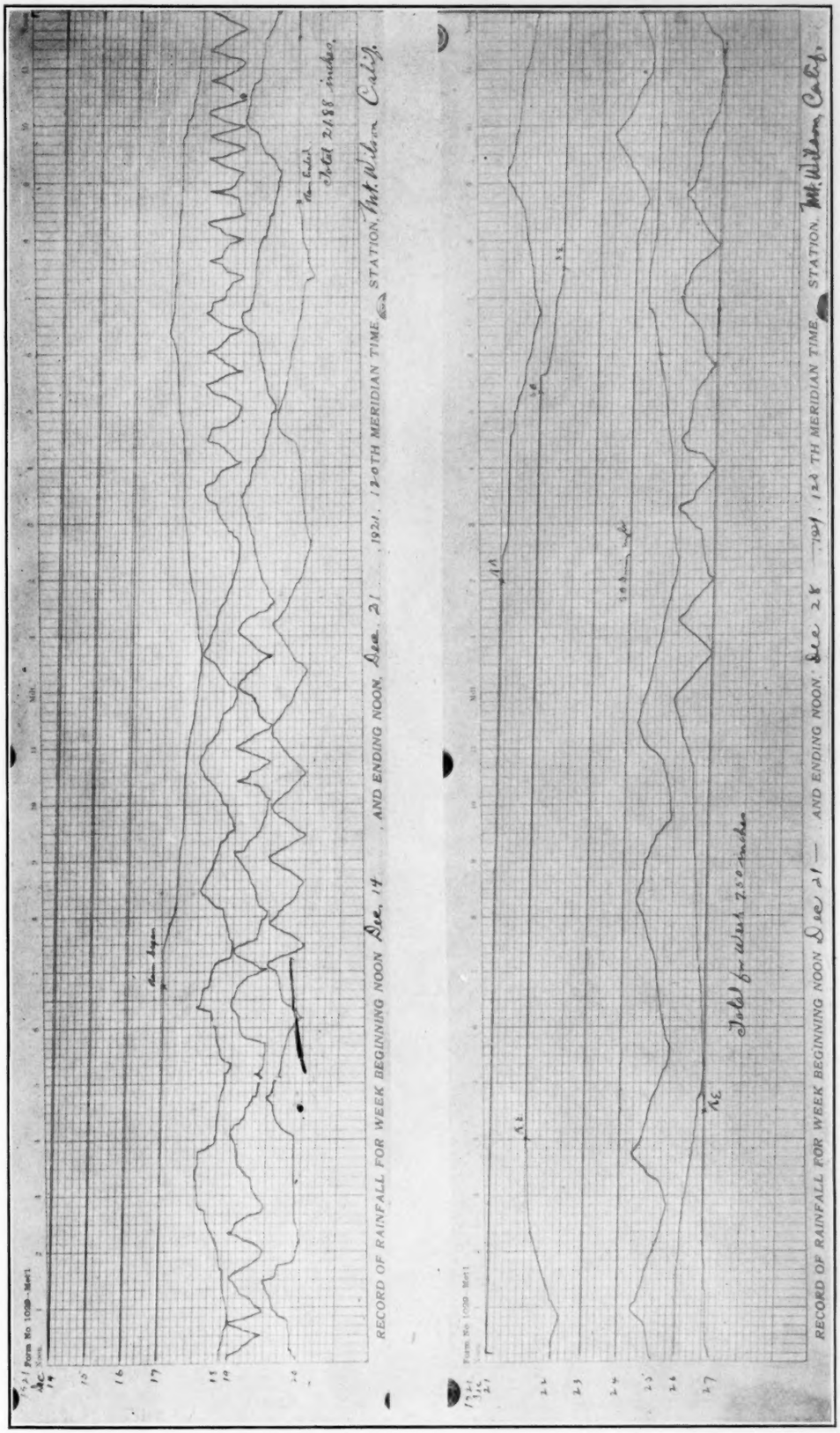
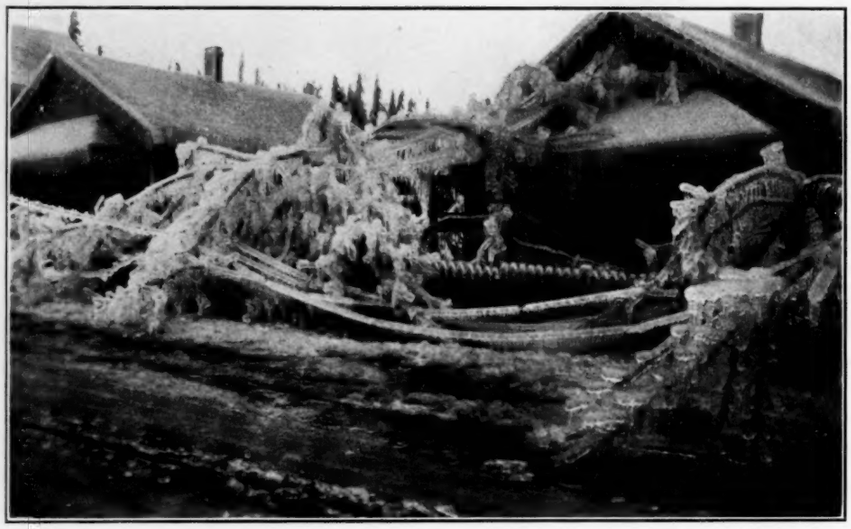

RECORD OF RAINFALL FOR WEEK BEGINNING NOON Dec. 14 AND ENDING NOON, Dec. 21 1921. 120TH MERIDIAN TIME STATION Mt. Wilson Calif.
RECORD OF RAINFALL FOR WEEK BEGINNING NOON Dec 21 — AND ENDING NOON Dec 28 — 1921. 120 TH MERIDIAN TIME STATION Mt. Wilson, Calif.

FIG. 1.—Record of Marvin Float Gage, Mount Wilson, Calif., Dec. 14-28, 1921.



FIGS. 4-5.—Effects of ice storm near Portland, Oreg.

The Marvin recorder gave a very perfect record, which is shown in the accompanying photograph of two sheets covering the two-week period, from noon December 14, to noon December 28.

The wind during the entire storm held steadily from S. to SSE., with an unusually high velocity, running 40, 50, and 60 miles per hour, reaching a maximum for a few minutes at one time of 80 miles per hour.

The temperature ranged from 40° to 45° day and night, dropping once to 22°, rising to the former figures again in a short time.

The runoff was rapid and as soon as the weather cleared the Santa Ana, San Gabriel, and Los Angeles Rivers could be plainly seen from the mountain top, spreading their waters out over the level lands adjacent to those streams, inundating many low-lying farms for a distance of 20 or 30 miles inland from the sea.

This storm came after a long period of dry weather, which is characteristic of this region. Only 1.48 inches had fallen since May 23, 1921.

A simple computation helps one to realize what an enormous amount of water falls to the ground from the clouds during such a storm. A fall of 29.38 inches of rain means 152.5 pounds of water to every square foot of surface, 33,214 tons per acre and 21,257,280 tons per square mile.

STORM OF NOVEMBER 19-22 IN OREGON, WASHINGTON, AND IDAHO, AND STORMY PERIOD FOLLOWING.

EDWARD LANSING WELLS, Meteorologist.

[Weather Bureau, Portland, Oreg., Jan. 9, 1922.]

A period of unusually stormy weather in the Pacific Northwest began with a sudden drop in temperature in eastern Washington on November 19, 1921, and closed with high wind and a remarkable rise in pressure on December 1 and 2. Prominent features of this stormy period were: a destructive ice storm from the vicinity of Portland eastward to the Columbia River Gorge on November 19 and 20; a very heavy fall of sleet and snow along the middle Columbia, and of snow in northeastern Oregon, southeastern Washington, and north-central Idaho, and phenomenally heavy rainfall west of the Cascades, from November 19 to 22; a rapid rise in temperature beginning at Portland on the 21st and reaching interior points on the 22d; and the continuance of mild, rainy weather during the remainder of November.

Chart E. L. W.–I (upper map) shows the weather map of the morning of November 18. Two well-defined areas of high pressure are apparent, one, of a continental type, central in the interior of western Canada, and carrying low temperature, and the other central off the northern California coast, and varying mild temperature, with a shallow trough of low pressure between. The lower map shows the center of the continental anticyclone to have advanced to eastern Montana, the trough of low pressure to have moved somewhat southward, and the coast high-pressure area to have remained nearly stationary. The temperatures in the immediate vicinity of the continental high had fallen rapidly. At Spokane, Wash., a cold wave occurred, the temperature falling to −1°. This is the earliest zero weather of record at that place.

Some snow fell in eastern Washington and Oregon and northern Idaho on the 17th, but the heavy snowfall began on the evening of the 18th and continued until the 21st. At Lewiston, Idaho, the snowfall amounted to 15.9 inches, which is the greatest November snowfall of record, and is within half an inch of the average annual snowfall for that place. At Walla Walla, Wash., the snowfall amounted to 19.9 inches, which is the greatest November snowfall of record at that place. On the evening of the 20th the total depth of snow on the ground at Walla Walla was 18.2 inches, which is, with one exception, the greatest depth of record at Walla Walla.

Along the middle reaches of the Columbia River the snowfall was greater, reaching a total of 54 inches of snow and sleet at The Dalles, Oreg.

In the gorge where the Columbia River passes through the Cascade Mountains the precipitation was largely in the form of sleet, which rolled down the steep slopes and accumulated many feet in depth in places on the Columbia River Highway and on the tracks of the O.-W. R. & N. Co., and the S. P. & S. R. R. Co. Many automobiles and several trains were stalled. Railroad service was restored in a few days, but at this writing, January 9, the highway is still blocked. The tremendous pressure of the masses of frozen sleet sliding down into the gorge caused some damage to the reinforced concrete viaducts on the highway.

From the Columbia River gorge to the lower Willamette Valley the storm took the form of unusually heavy rain, partly freezing as it fell, forming a heavy coating of ice on trees, poles, wires, and roofs. Sleet and ice were experienced to some extent over large areas in eastern and southern Washington and northern Oregon, and to a limited extent in north-central Idaho, but the deposit of ice was greatest from the Columbia River gorge to the vicinity of Portland. Street-car service was obstructed, power, telephone, and telegraph lines running east from Portland were almost completely ruined, and at one time 9,000 telephones in Portland were out of commission.

The lowest temperature reached at the Weather Bureau office in Portland was 29°, on the 20th, and by the evening of the 20th the temperature had risen above the freezing point and the ice in the business district had disappeared. In the eastern portion of the city it did not disappear till the afternoon of the 21st.

During the prevalence of the ice storm the wind at Portland was almost constantly from the east. Shortly before 4 p. m. on the 21st it was noted that the lower clouds, which had been moving from the east, were moving rapidly from the southwest, and in a few minutes the wind changed to south, increasing in force. In half an hour the temperature had risen from 40° to 56°.

This sudden rise in temperature reached eastern Washington, northeastern Oregon, and northern Idaho about 12 hours later, but was not felt in southern Oregon, southeastern Oregon, southern Idaho, nor on the coast. Thermograph traces from selected stations are shown in figure 1. The rise in temperature was greatest at Walla Walla, Wash., amounting to 32° in five hours.

Figure 2 shows the distribution of precipitation in Oregon for the four-day period, November 19–22. The precipitation reached a maximum of 13.03 inches at Zigzag Ranger Station, near Welches, on the west slope of Mount Hood, at an elevation of 1,435 feet.

At that place there was only 1 inch of snowfall, at and Government Camp, the highest station in northwestern Oregon, elevation 3,890 feet, the total snowfall for the

4 days was only 31 inches, and the total depth of snow on the ground at Government Camp decreased from 54 inches on the 19th to 8 inches on the 21st, while at The Dalles, elevation 96 feet, the fall of snow and sleet amounted to 54 inches. At Government Camp the lowest temperature during the period was 28°, while at The Dalles the lowest was 19°.

The charts and records indicate that during the storm there were two well-defined opposing currents of air; one a cold one, blowing out from the continental high, and the other a mild, moist one, blowing in from the ocean. The cold current, being heavier, underran the mild, moist current. Elevation of the moist current, due to the cold current beneath, and to the mass of the Cascade Mountains, cooled it sufficiently to cause rapid condensation, but not until it had advanced to a considerable distance inland was it sufficiently cooled to form snow. Near the coast and on the western slope of the Cascade Mountains the precipitation occurred as rain. From the lower Willamette Valley eastward to the Columbia River Gorge the precipitation reached the ground as rain, but in entering the cold easterly current it was so cooled that it froze as it struck, forming a heavy coating of ice on exposed surfaces. In the Gorge and over parts of the middle Columbia Valley, rain falling through the cold lower stratum was frozen into small globes of ice, which, to quote Mr. Samuel C. Lancaster, builder of the Columbia River Highway, "rolled down the slopes like wheat from a hopper." Farther inland the upper current became sufficiently cooled so that precipitation occurred as snow.

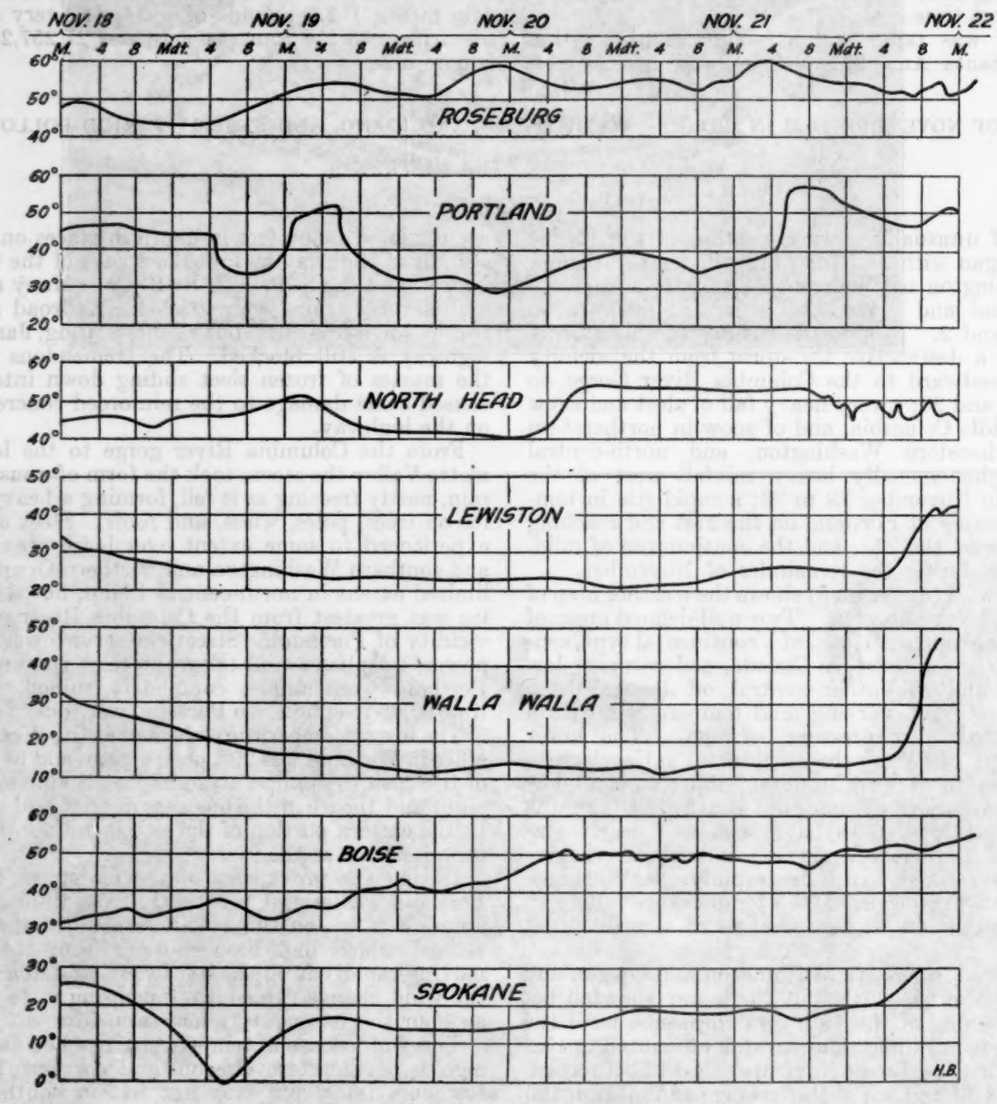
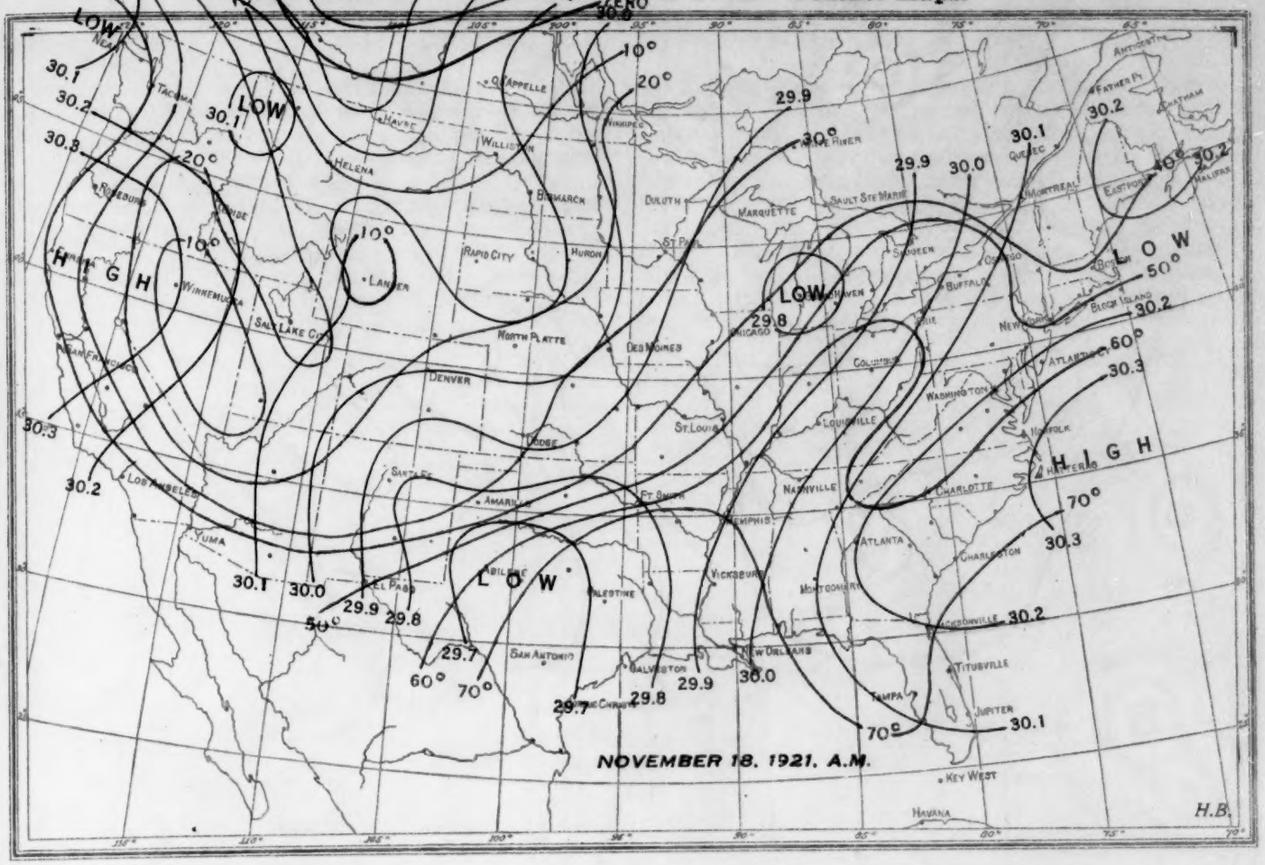


FIG. 1.—Thermograph traces from selected stations, Nov. 19–22, 1921.

Referring again to figure 1, it will be noted that during a large part of the period under discussion, Roseburg, Oreg., and North Head, Wash., had the mild temperature typical of winds from the ocean; at Boise, Idaho, the temperature rose gradually to about the same degree and then remained nearly constant; Spokane, Wash.; Walla Walla, Wash., and Lewiston, Idaho, had low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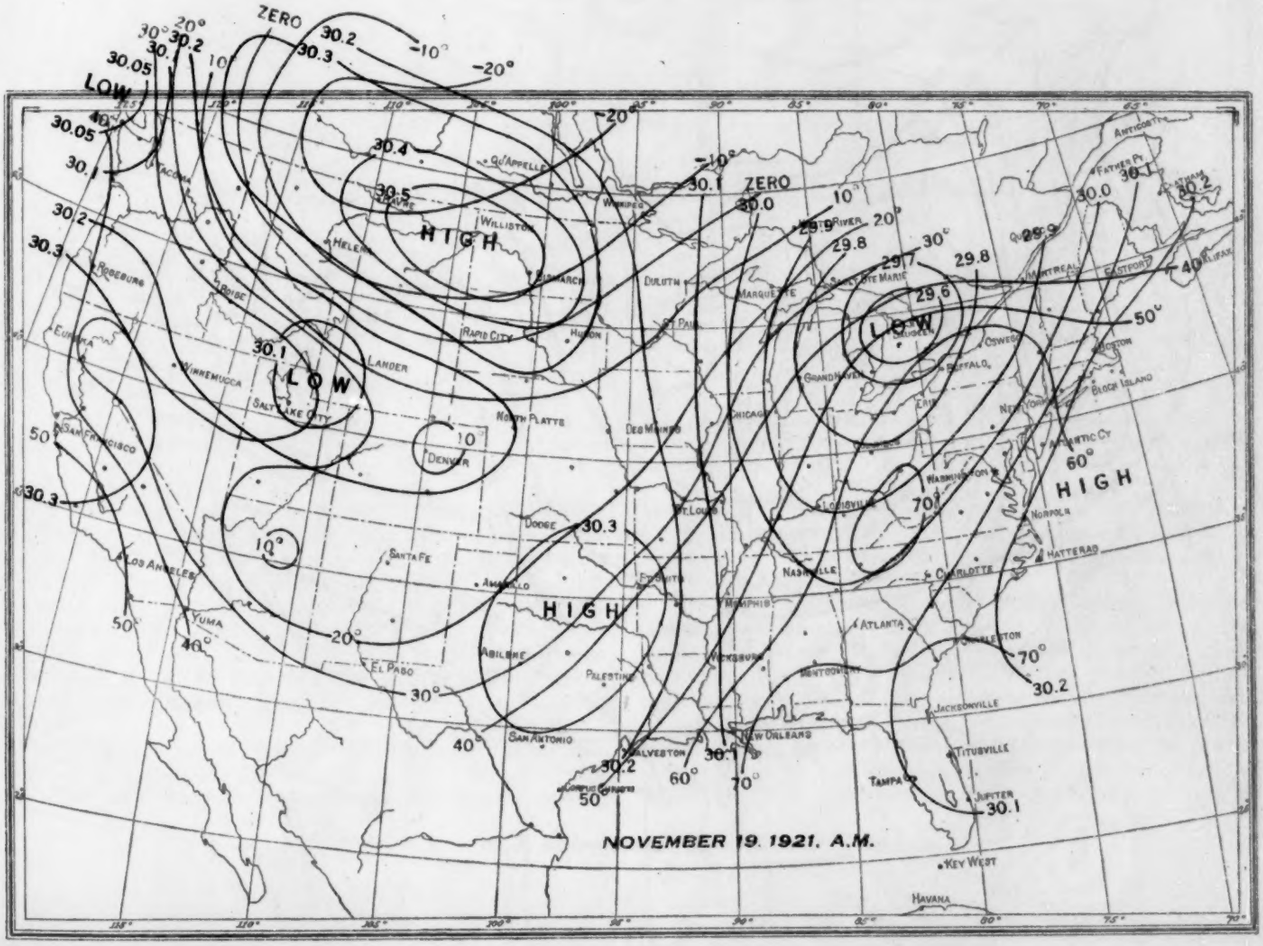
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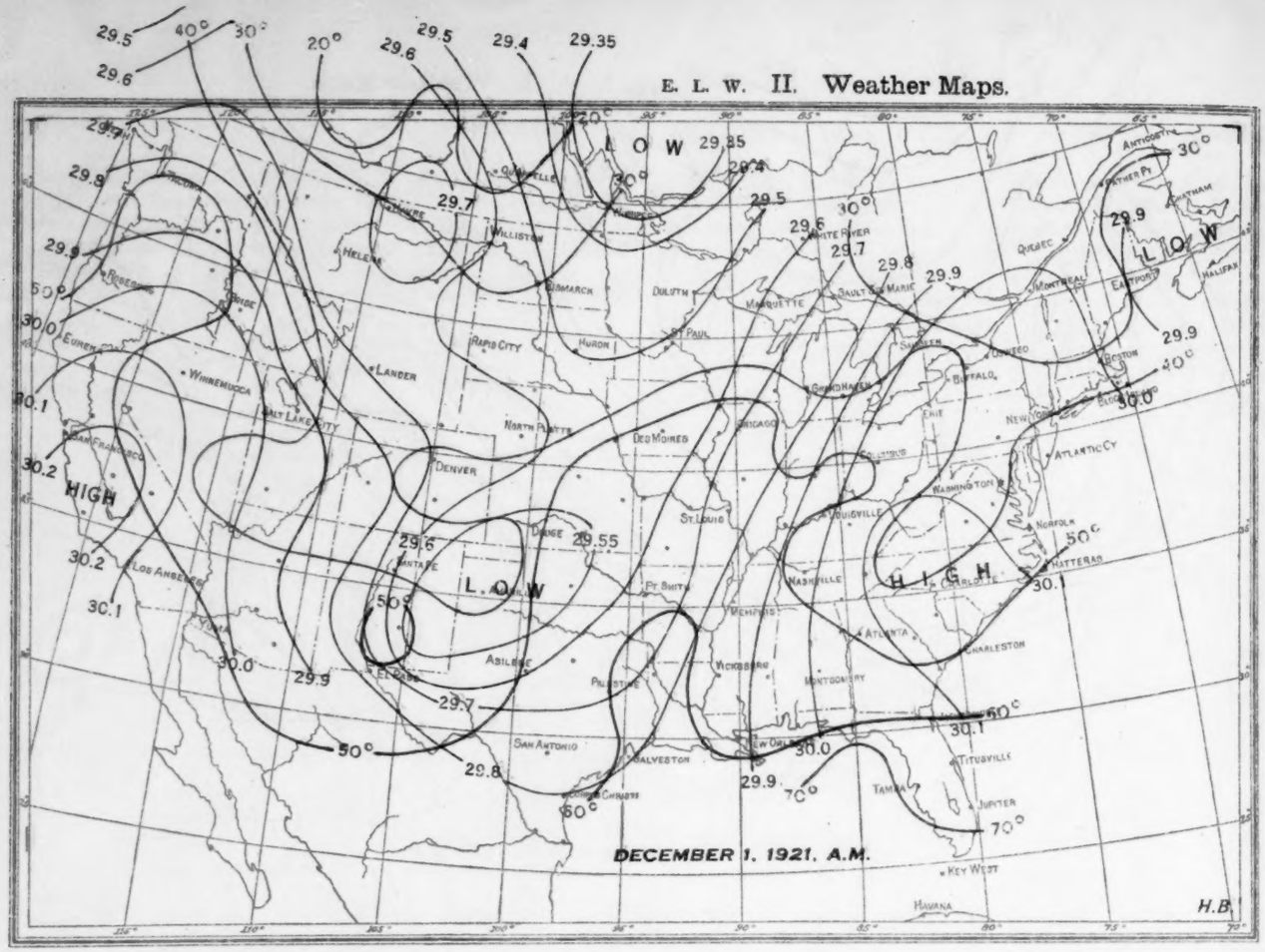
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DECEMBER 1. 1921. A.M.
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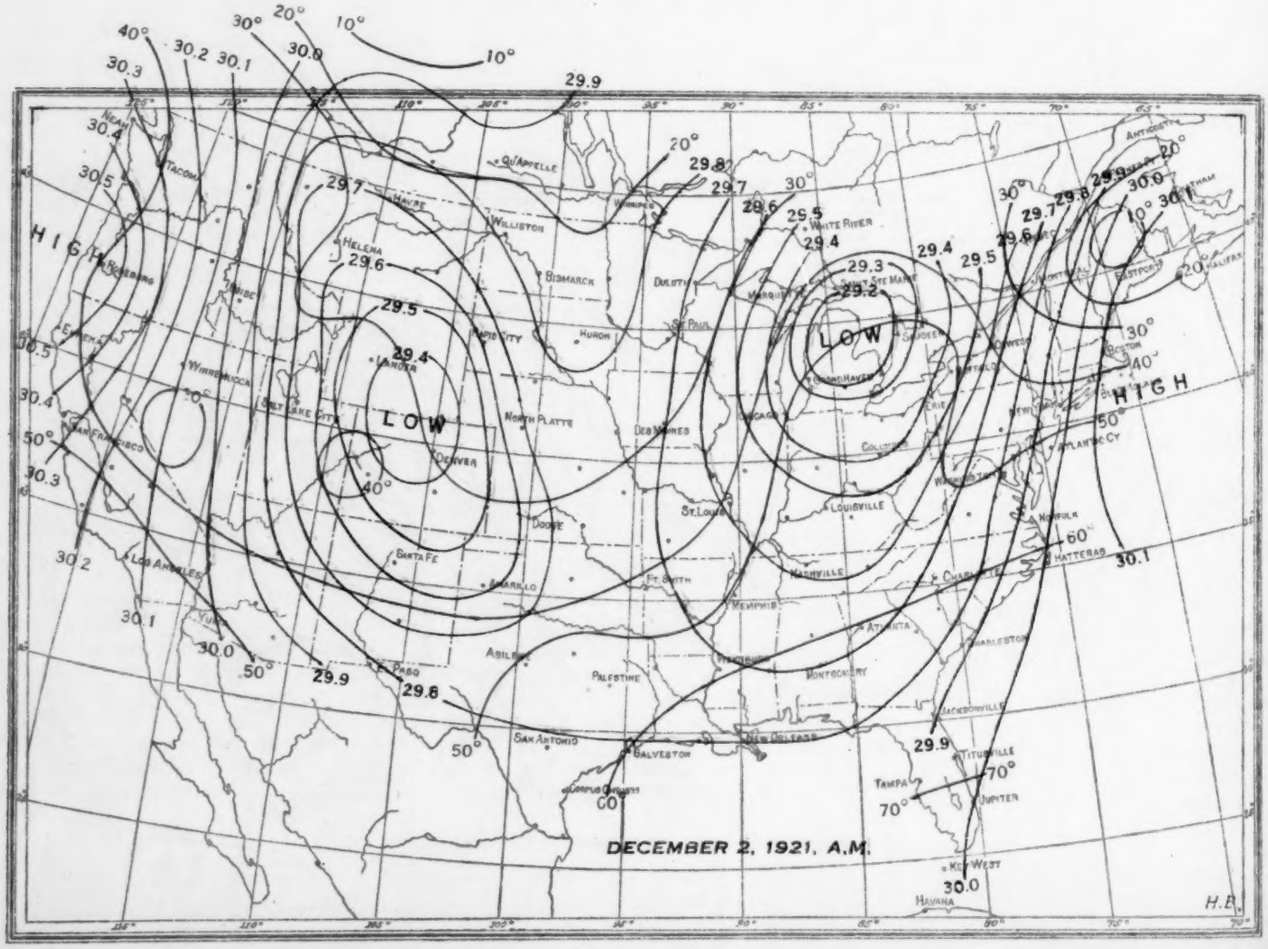
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DECEMBER 2. 1921. A.M.
H.B.

temperature, which was quite uniform except for the sudden fall and subsequent rise at Spokane on the 19th.

Portland, being near the western end of the Columbia River Gorge, where the conflict between the two currents was most active, was part of the time under the influence of one current and part of the time under the influence of the other. Up to 4 a. m. on the 19th the wind was southwest and south, and the temperature was nearly the same as at Roseburg and North Head. At 4 a. m. on the 19th the wind changed to east and the temperature fell rapidly. Shortly after noon the wind went to south and the temperature again approached that of Roseburg and North Head, ice that had begun to form in the eastern portion of the city disappeared, and it was believed that the danger of a serious ice storm had passed. At 6 p. m. the wind went to northwest and the temperature again fell very rapidly. By 11 p. m. the wind was northeast and by 1 a. m. it was east. When the wind changed to south at 4 p. m. on the 21st the temperature quickly rose to approximately that of Roseburg and North Head.

The remainder of the month was unusually mild and rainy over the entire Pacific Northwest. Runoff from rain and from melting snow in the mountains caused rapid rises in most of the rivers in western Oregon and Washington. Flood stages were exceeded in the Willamette, Yamhill, Clackamas, McKenzie, and Santiam Rivers, and considerable damage was done by the overflow of the Santiam River near where it empties into the Willamette.

This period of unusually stormy weather came to a close in the opening days of December with the rapid movement inland of an area of very low pressure, which was closely followed by one of the most pronounced areas of high pressure ever known in this section. This movement is shown in figure 3, which gives the barograph traces for representative stations, and in Chart E. L. W. II, which presents the weather maps for the mornings of December 1 and 2.

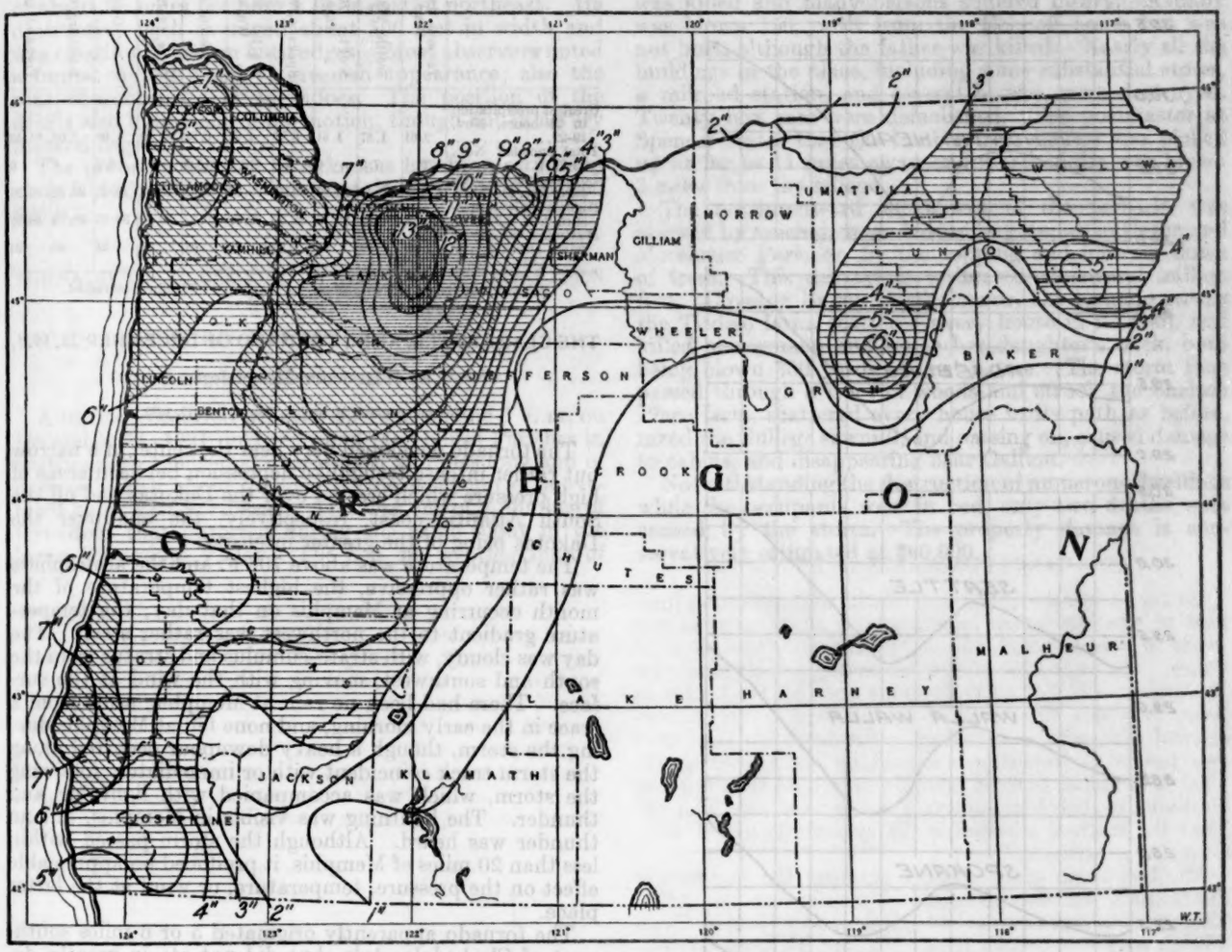

FIG. 2.—Distribution of precipitation in Oregon, Nov. 19-22, 1921.

This movement was attended by high winds, which in some places caused much damage to trees, wires, and roofs. At Portland the wind reached a velocity of 42 miles an hour, from the west. This is the highest velocity recorded at Portland since the anemometer was placed in its present location. At North Head the wind reached a maximum velocity of 90 miles from the northwest. This is the highest velocity ever recorded at North Head from the northwest.

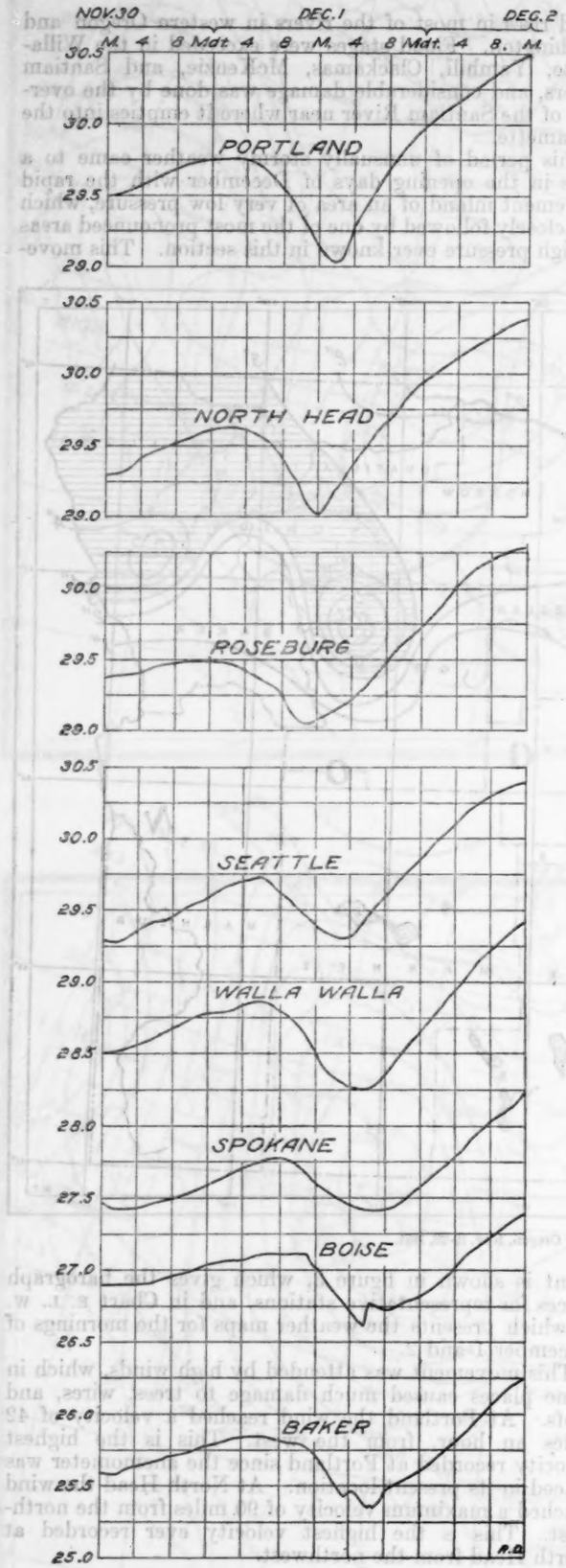

FIG. 3.—Barograph traces from selected stations, Dec. 1-2, 1921.

The official in charge of the Weather Bureau office at Roseburg reports that wild geese were heard all night on November 30-December 1, going south, and apparently flying low.

Table I gives some of the more important weather data for the period under discussion.

TABLE 1.—*Meteorological data for various stations, Nov. 19–22 and Dec. 1–3, 1921.*

	Tatoosh Island, Wash.	Seattle, Wash.	North Head, Wash.	Spokane, Wash.	Walla Walla, Wash.	Lewiston, Idaho.	Boise, Idaho.	Baker, Oreg.	Roseburg, Oreg.	Portland, Oreg.
Greatest precipitation in 24 hours, Nov. 19–22	2.61	1.57	1.51	0.16	1.21	0.88	*1.00	1.08	2.09	*1.43
Total snowfall Nov. 19–22	T.	7.3	0	7.4	*19.9	*15.9	0.4	6.3	0	0
Lowest sea-level pressure, Dec. 1	.....	29.43	29.26	29.40	29.33	29.38	29.41	29.42	29.40	29.22
Highest sea-level pressure, Dec. 2–3	†30.78	†30.83	30.76	30.79	30.78	30.84	30.79	30.83	30.74	30.77
Maximum velocity of wind, Dec. 1–2	56	39	90	29	27	31	31	24	40	24

*Greatest on record for November. †Highest on record.

THE CLARKEDALE, ARK., TORNADO OF DECEMBER 23, 1921.

By J. H. SCOTT, Meteorologist.

[Weather Bureau, Memphis, Tenn., Jan. 12, 1922.]

The tornado developed very near the center of a narrow but rather intense troughlike depression between areas of high pressure which crested over the Dakotas and off the South Atlantic coast, respectively, the one over the Dakotas being of the greater intensity.

The temperature was above 70° F. and the atmosphere was rather oppressive, the highest temperature of the month occurring at Memphis on that day; the temperature gradient to the northwest was rather steep. The day was cloudy, with strato-cumulus and stratus from the south and southwest, moving with the wind at the surface. There had been no rain at Memphis, aside from a trace in the early morning, and none fell at Memphis during the storm, though a heavy downpour occurred along the storm track coincident with or immediately following the storm, which was accompanied with lightning and thunder. The lightning was visible in Memphis, but no thunder was heard. Although the storm passed within less than 20 miles of Memphis, it produced no appreciable effect on the pressure, temperature, or wind at the latter place.

The tornado apparently originated 5 or 6 miles southwest of Clarkedale, Ark., but did not attain greatly destructive force until it struck the Booker farm, some 2 miles from Clarkedale, where several buildings were wrecked and two persons were killed. Continuing its northeastward course, the tornado struck the town of Clarkedale squarely, wrecking the majority of the buildings, including the large brick plantation store of Banks & Danner, where 40 or 50 persons were doing their Christmas shopping or had taken refuge from the advancing storm. One white and three colored men lost their lives in the collapse of this building. The total death list from the storm was 6, while the seriously injured numbered about 15. Besides the plantation store, a large cotton gin, several warehouses, a number of substantial residences, and 40 or more plantation cabins were wrecked. The cabins were of frail construction,

and though most of them were occupied there was no loss of life in their destruction. Fortunately the cotton gin was not in operation that day; if it had been, the loss of life would probably have been considerably greater.

The tornado apparently lifted at the Mississippi levee, about 15 miles from its point of origin, but descended again in Tipton County, Tenn., doing more or less property damage in the vicinity of Phelan, a village 10 or 12 miles southeast of Covington, where two persons were slightly injured in the collapse of a brick store building.

The tornado struck Clarkedale at about 4 p. m. and Phelan near 5.15 p. m., indicating a velocity of translation of about 35 miles per hour a little east of northeast. Its destructive path averaged about 500 feet in width and was clearly marked on both edges. Most observers noted a funnel-shaped cloud of greenish appearance; also the roar characteristic of tornadoes. The position of the débris also indicated rotary motion, though not in a very marked degree.

The property damage in Arkansas has been estimated at $150,000, while in Tennessee it will hardly exceed $20,000.

TORNADO OF DECEMBER 24, 1921, IN NORTHEASTERN LOUISIANA.

By RAY A. DYKE, Meteorologist.

[Weather Bureau Office, New Orleans, La., Jan. 24, 1922.]

A tornado occurred between 12:10 a. m. and 1 a. m. on December 24, 1921, in Union and Morehouse Parishes in northeastern Louisiana, over a path 25 miles long and of average width about 200 yards, the direction of movement being east-northeast. This was one of a number of tornadoes that occurred during the same night in the lower Mississippi Valley. The 8 p. m. weather map of December 23 showed a well defined, long, narrow trough of low atmospheric pressure over the Ohio Valley, Arkansas, northern Mississippi, northwestern Louisiana, and eastern Texas, with temperatures in the trough ranging from 68 to 72 except in the Ohio Valley. With these conditions the shift of the wind to the west and northwest, bringing air 30° to 35° colder, should have taken place at or near the time of the occurrence of the tornadoes.

The tornado in Louisiana appears to have originated just southwest of Spencer, a village which was in the path of the storm and suffered great damage. One man was killed and many persons suffered injury. A baby was blown 150 yards from the Eckhoff home but was not hurt, although the father was killed. Nearly all the buildings in the place, including some substantial stores, a railroad station, and several houses, were destroyed. Twenty box cars were demolished. The postmaster at Spencer states that the lumber from houses was picked up as far as 11 miles away and merchandise was blown 3 miles from the village.

The northeastward movement of the tornado was marked by much damage to standing timber in Union and Morehouse Parishes, by the topping and blowing down of trees. This damage is estimated at several million feet. Crossing Bayou Bartholomew, the tornado struck the Tisdale farm, scattered every house in its trail, and killed one woman and broke her daughter's back, both being blown 300 yards against a tree. The storm then passed through a tract of woods and struck the Shelton Place farm, scattered every house in its path as before, razed the Gullege sawmill, and passing on, caused damage to cabins, and disappearing near Gallion.

Notwithstanding the destruction of numerous dwellings while the occupants were in bed, only two deaths were caused by the storm. The property damage is conservatively estimated at $60,000.

NOTES, ABSTRACTS, AND REVIEWS.

CLIMATIC OR CALENDAR YEAR?

A board composed of Central Office officials of the Weather Bureau was appointed on June 15, 1921, to be known as the Board On Rainfall Observations and Severe Local Storms. Among the subjects considered by that board was that of printing statistics of rainfall on the basis of a climatic rather than the calendar year. The Board endeavored by several means to ascertain the views upon such a change that were held by engineers and other users of rainfall data. Finally it was deemed advisable to circulate a questionnaire through the medium of the MONTHLY WEATHER REVIEW. The questionnaire was inclosed in the July, 1921, REVIEW. To date about 1 per cent of the questionnaires have been returned. A poll of the replies shows that no definite conclusion was reached, the number of votes being very equally divided between the affirmative and the negative. The board therefore concludes that for the United States proper, excluding California, no change from present practice is desirable. For California the data will be published on the basis both of a calendar and a climatic year. The latter to begin with July 1 and to end with June 30.

The discussion brought out no new viewpoints; a number of those opposed to the change seemed to adopt the idea expressed by a member of the engineering staff of a western university, as follows:

> What we desire in the Government publication is the record, and that is best preserved and referred to by the calendar year. If any engineer or meteorologist wants to make any arbitrary division into "climatic" years it would seem a simple matter to do so.

—*A. J. H.*

LONG-RANGE FORECASTS IN ENGLAND.

So far as is known, the first official and authentic forecast of weather for as long a period as two weeks was made in September, 1921, by the British Meteorological Office. On page 279, of the *Meteorological Magazine* for November, 1921, is to be found a note by E. V. Newnham, in which this forecast is discussed. The *Meteorological Magazine*, in introducing the note, mentions that two points of importance should be emphasized: "(1) That it is not at present possible to extend the 'Further Outlook' to such long intervals as a general rule, and (2) That the method adopted is the systematic use of well-classified experience."

Mr. Newnham gives a figure showing the barometric distribution on the morning of September 26, 1921. There was a large anticyclone, classified by Gold as Type VIIIB, over the British Isles. "This," he says, "is obviously a very favorable type for dry weather at any time of year. Additional reasons existed for expecting prolonged fair weather on this occasion, such as would not generally apply to other cases of Type VIIIB * * *." Upon examination of past records when this type of anticyclone occurred, in September, it was found that only once in the seven occurrences since 1907 did the break-up of the weather control occur in less than a fortnight. Upon this basis the following forecast was issued on September 26:

> Mainly fair and dry weather is probable for the next week or 10 days over the southern half of the Kingdom.

Two days later this was supplemented by the statement:

> Over the eastern and central parts of England, south of the Humber, the chances are distinctly against a definite break up of these conditions within the next fortnight.

In discussing what actually happened, the writer shows that the 10-day forecast was not wholly successful for part of the area referred to, but that the 14-day forecast for the eastern counties was successful.

He concludes:

> The large area covered by the working charts of to-day should make it possible to attempt further long-period forecasts of the general character of the weather from time to time. It seems not unreasonable to hope for greater success with these than with regular 24-hour forecasts of the detailed character of the weather, since the minor eccentricities of the weather, which so often cause failure in a 24-hour forecast, become relatively unimportant during the longer period.

In this connection it is interesting to note that in Mr. E. H. Bowie's chapter on "Long Range Weather Forecasts," in *Weather Forecasting in the United States*, page 347, he points out the possibility of using HIGHS in this manner. "When these conditions of pressure distribution," he says, "become firmly established the forecaster is able to take advantage of them and thus to extend the outlook generally as much as a week beyond the 36-hour period of the morning forecast."—*C. L. M.*

NOCTURNAL RADIATION ON MOUNT BLANC.

By A. BOUTARIC.

[Abstracted from *Comptes Rendus*, Dec. 19, 1921, pp. 1392-1394.]

This paper is based upon observations of nocturnal radiation made on Mount Blanc (4,350 meters altitude) between July 30 and August 7, 1921. These observations with which only those made by Anders Ångström on Mount Whitney, Calif. (4,420 meters altitude), are comparable, were made with an Ångström actinometer. From his observations the author computed the following values of the ratio between the nocturnal radiation and the radiation of a black surface at the absolute temperature θ_0, where $\theta_0 = t_0 + 273$, t_0 being observed:

Aug. 1	0.400
2	.326
5	.415
6	.379

When the measures made by registering instruments were studied, it appears that the maximum occurs a little after sunset and decreases slightly through the night. This observation agrees with others by the author at Montpellier and on the Pic du Midi, much lower stations. This result is contrary to that obtained by LoSurdo at Naples and Exner on the Sonnblick.

Contrary to the general opinion, nocturnal radiation at great altitudes is not exceptionally intense, and is of the same order of magnitude as lower stations. The observations on Mount Blanc give practically the same result as those by Ångström on Mount Whitney.—*C. L. M.*

VARIATIONS OF THE WATER TEMPERATURES OF THE ATLANTIC OFF THE FRENCH COAST.

By E. LE DANOIS.

[Abstracted from *Comptes Rendus* (Paris Acad.), Nov. 14, 1921, pp. 923-925.]

In carrying out the program of the Committee on the Atlantic Plateau, appointed by the International Council for the Exploration of the Sea, divers cruises were made this summer (1921) off the coast of France between Spain and Ireland. Sufficient observations have been made to reach the specific conclusions concerning the Atlantic waters from point of view of temperature.

The continental plateau, from the entrance of the English Channel, is covered with cold water, the continuance of the waters of the north of Europe which represent there the mean or normal waters; their temperature on the bottom varying little from 9° to 12° C. at the maximum. From December to April these waters are spread out in stable, isothermal sheets.

In summer, from May to November, an important "transgression" of the warm waters is produced, localized in upper layers down as far as 60 meters. Below 60 meters, the layers of water can not be said to be affected by this warm extension, their temperature being 11° on the continental plateau and 12° outside the plateau.

The depth where the "transgression" is best marked is at 50 meters. Rounding Cape Finisterre, the sheets at a temperature of 17° to 18° force themselves into the Gulf of Gascony, between 45° and 46° N. Toward the north, this sheet forms three large expansions which infringe on the edge of the continental plateau: (1) In the region southwest of Ireland, 50° N.; (2) to the east of the bank of the Petite Sole, as far as 49° 20′ N.; (3) to the southwest of Penmarch. The cold waters of the plateau find themselves thrown back and canalized.

Between the second and third warm "transgression" is found a sheet of water, the length of Parson's bank, which is flattened out toward the south, outside of the plateau, as far as 46° N. The same phenomenon has been found off the Spanish coast in longitude 7° W. On this meridian a veritable "cold sill" is formed whose width does not exceed 60 miles.

Thus, on the French continental plateau at a depth of 50 meters the summer transgression of the warm waters from three pockets is limited by the cold waters of this plateau, which they throw back and force to spread out in two points.

The order of things in the channel is entirely different from these waters of the Atlantic, observations leading to the belief that the former and the North Sea are closely connected.

The great variability of temperature in the Channel is in contrast to that of the Atlantic waters of the continental plateau, and a barrier of cold water, which extends from Ouessant to the Scilly Islands, forms a veritable separation between the Atlantic waters and those of the Channel.

The phenomena which we have cited are constant, they are susceptible to variation, but the general principle remains the same, observations made the past two years confirming this.

In looking at this group of phenomena from the point of view of general hydrography, we must consider that the continental plateau at the entrance of the Channel corresponds to the banks of Newfoundland on the American coast, in the sense that it is the seat of a marked opposition of warm and cold waters. This opposition is more intense on the American coast in consequence of the large accumulations of cold water coming from the icebergs and the warm water coming up from the Gulf of Mexico, than on the coast of Europe, but the correspondence phenomenon of the two Atlantic coasts, nevertheless, remains complete.—*G. F. H.*

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1921.

By HERBERT H. KIMBALL, Meteorologist.

[Solar Radiation Investigations, Weather Bureau, Washington, January 27, 1922.]

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, 48:225.

Table 1 indicates that solar radiation intensities averaged slightly above the December normal at Madison, Wis., and Santa Fe, N. Mex., and very close to normal at Washington, D. C., and Lincoln, Nebr. At the first two named stations there were few days on which measurements could be obtained, however.

Table 2 shows that the total radiation received on a horizontal surface was below the normal for December at both Washington and Madison, the deficiency at each station being more marked during the first half than during the second half of the month.

For the year 1921, the last two columns of Table 2 show that at Washington the accumulated excess of radiation was 1.4 per cent of the annual normal, and at Madison the accumulated deficiency was 3.7 per cent. Practically all this latter was accumulated before the end of April, however.

Skylight polarization measurements made on four days at Washington give a mean of 55 per cent and a maximum of 65 per cent on the 28th. These are slightly below the average December values for Washington. At Madison snow covered the ground during most of the month. A measurement made on the 10th, when the ground was free from snow, gave a percentage of polarization of 72, or about the average for December for that station.

TABLE 1.—*Solar radiation intensities during December, 1921.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 1	5.56	0.68	0.78	0.89	1.17	.....	.....	.....	.....	.....	5.36
3	4.57	0.66	0.87	1.09	1.19	.....	.....	0.92	0.84	.....	3.45
6	2.62	.....	0.94	.....	1.32	.....	.....	.....	.....	.....	3.00
7	2.74	.....	0.59	.....	1.22	.....	.....	.....	.....	.....	3.15
10	3.63	.....	0.66	0.86	1.14	.....	.....	.....	.....	.....	4.95
15	2.16	.....	0.85	1.04	.....	.....	.....	1.04	0.80	0.62	2.62
17	4.95	.....	.....	0.91	.....	.....	.....	.....	.....	.....	6.02
20	3.63	.....	.....	0.72	.....	.....	.....	.....	.....	.....	3.99
22	0.96	1.05	1.16	1.27	.....	.....	.....	.....	.....	.....	1.19
27	3.45	.....	0.86	1.02	1.27	.....	.....	1.07	0.86	0.74	3.99
28	2.49	1.01	1.13	1.23	1.29	.....	.....	.....	.....	.....	2.74
Means	.....	**0.85**	**0.87**	**1.00**	**1.23**	.....	.....	**1.01**	**0.83**	**(0.68)**	.....
Departures	.....	**+0.08**	**−0.01**	**−0.04**	**+0.01**	.....	.....	**−0.02**	**−0.05**	**−0.09**	.....

Madison, Wis.

Dec. 10	3.99	0.98	1.09	.....	.....	.....	.....	.....	.....	.....	4.17
27	0.74	1.06	1.20	1.32	.....	1.59	.....	.....	.....	.....	1.37
29	1.24	1.11	1.21	1.33	.....	1.59	.....	.....	.....	.....	1.37
Means	.....	**1.05**	**1.17**	**(1.32)**	.....	.....	.....	.....	.....	.....	.....
Departures	.....	**+0.10**	**+0.03**	**+0.10**	.....	.....	.....	.....	.....	.....	.....

* Extrapolated.

TABLE 1.—*Solar radiation intensities during December, 1921*—Con.

Lincoln, Nebr.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 5	3.81	.....	.....	1.22	.....	.....	.....	1.25	1.12	1.04	3.81
6	2.87	.....	0.84	1.06	.....	.....	.....	.....	.....	.....	3.45
8	2.36	.....	1.07	1.27	.....	.....	.....	1.21	1.07	0.95	4.75
9	3.30	0.97	1.10	1.26	.....	.....	.....	.....	.....	.....	2.16
10	3.99	.....	.....	1.31	.....	.....	.....	.....	.....	.....	4.57
13	4.75	.....	.....	.....	.....	.....	.....	1.19	1.04	0.90	4.17
17	2.26	.....	.....	1.26	.....	.....	.....	.....	.....	.....	2.06
19	2.26	.....	.....	.....	.....	.....	.....	0.99	0.71	0.62	3.63
24	0.46	.....	1.12	1.26	.....	.....	.....	1.28	1.14	1.00	0.91
28	3.45	.....	.....	.....	.....	.....	.....	1.23	1.05	0.89	3.63
Means	.....	**(0.97)**	**1.03**	**1.23**	.....	.....	.....	**1.19**	**1.02**	**0.90**	.....
Departures	.....	**+0.06**	**−0.02**	**+0.01**	.....	.....	.....	**−0.01**	**−0.04**	**−0.05**	.....

Santa Fe, N. Mex.

Dec. 12	2.62	.....	.....	1.36	.....	.....	.....	.....	.....	.....	3.15
13	3.81	.....	1.24	1.35	1.48	1.61	.....	1.43	.....	.....	3.63
17	1.45	1.25	1.35	1.46	1.55	1.65	.....	1.43	1.21	.....	1.96
Means	.....	**(1.25)**	**(1.30)**	**1.39**	**(1.52)**	.....	.....	**(1.43)**	**(1.21)**	.....	.....
Departures	.....	**+0.09**	**+0.04**	**+0.03**	**+0.02**	.....	.....	**+0.12**	**±0.00**	.....	.....

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Dec. 3	142	118	.....	−15	− 5	.....	+1826	−4326	.....
10	137	84	.....	−16	−41	.....	+1714	−4611	.....
17	161	124	.....	+ 8	− 4	.....	+1772	−4642	.....
24*	152	162	.....	− 3	+31	.....	+1750	−4427	.....

* For eight days.

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, Jan. 25, 1922.]

In continuation of preceding publications, in the following table are given the results for the solar constant of radiation obtained at Montezuma, near Calama, Chile, in August, September, October, November, and for the first half of December, 1921. The values for the remainder of December will be given with the January values when they shall have been received.

From now on, we give $\rho/\rho sc$ at air mass 2. The reader is referred for further statements regarding the arrangement and meaning of the table to the REVIEW for February, August and September, 1919.

For an account of the circumstances surrounding the recent delay in the publication of these data, see pp. 651–652 of this REVIEW.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. ρ/ρs. c.	Humidity. V. P.	Humidity. Relative humidity.	Remarks.
1921							*Per cent.*	
A. M.	*cal.*					*cm.*		
Aug. 2...	1.912	E_0	VG..	0.879	0.633	0.30	33	Cloudless. Evidence of increasing water vapor.
	1.942	$M_{2.5}$						
	1.914	M_2						
	1.949	$M_{1.5}$						
	1.935	W. M.						
P. M.								
Sept. 24...	1.937	E_0	VG−	.875	.627	.21	18	Clear around sun. Very heavy west wind.
A. M.								
25...	1.963	E_0	VG+	.876	.696	.27	26	Good sky.
	1.968	$M_{1.4}$						
	1.965	W. M.						
P. M.								
27...	1.970	E_0	VG+	.876	.644	.10	8	Good sky early, but cirri forming near sun during last obeservations.
	1.929	M_3						
	1.946	$M_{3.5}$						
	1.954	W. M.						
A. M.								
28...	1.972	E_0	E−	.880	.657	.32	41	Distant cirri all morning. Cirri interfered with 4th bolograph.
	1.929	M_3						
	1.945	$M_{1.4}$						
	1.953	W. M.						
30...	1.956	E_0	VG..	.882	.681	.10	10	Good sky.
	1.976	M_3						
	1.953	$M_{3.4}$						
	1.951	M_2						
	1.939	$M_{1.5}$						
	1.955	W. M.						
P. M.								
Oct. 3...	1.933	E_0	VG..	.876	.594	.09	4	Good sky. Strong west wind.
	1.924	M_3						
	1.934	$M_{2.5}$						
	1.972	$M_{1.5}$						
	1.930	W. M.						
4...	1.966	E_0	E....	.875	.599	.17	9	Do.
	1.950	$M_{2.4}$						
	1.957	M_2						
	1.963	$M_{1.4}$						
	1.959	W. M.						
A. M.								
5...	1.939	E_0	E....	.879	.649	.21	19	Do.
	1.931	$M_{2.4}$						
	1.935	M_2						
	1.945	$M_{1.4}$						
	1.938	W. M.						
P. M.								
6...	1.983	E_0	VG+	.877	.597	.16	8	Do.
	1.949	$M_{1.5}$						
	1.960	W. M.						
A. M.								
7...	1.967	E_0	E−..	.876	.622	.15	16	Cloudless. Much low haze.
	1.925	$M_{3.4}$						
	1.945	M_2						
	1.959	$M_{1.5}$						
	1.952	W. M.						
P. M.								
8...	1.937	E_0	VG..	.875	.589	.19	9	Cloudless in west. Strong west wind
	1.949	$M_{3.4}$						
	1.911	$M_{1.5}$						
	1.932	W. M.						
A. M.								
9...	1.931	E_0	VG+	.865	.537	.16	15	Distant cirri in east. Low haze.
	1.927	M_2						
	1.929	W. M.						
P. M.								
10...	2.023	E_0	VG..	.829	.471	.19	12	Sky hazy and streaky. Strong wind from west.
13...	1.957	$M_{1.25}$	S−...	.878	.653	.13	6	Some distant cirri. Stong west wind.
	1.931	$M_{1.4}$						
	1.944	W. M.						
16...	1.962	$M_{2.32}$	S−...	.869	.505	.19	14	Scattered cirro-cumulus. Heavy west wind.
18...	2.001	E_0	VG..	.874	.629	.18	11	Poor sky. Scattered cirri, interfering with last observation.
22...	1.938	E_0	VG..	.875	.671	.17	11	Cirri in east. Strong west wind.
A. M.								
23...	1.975	E_0	E−..	.871	.604	.16	18	Distant cirri. Quite hazy.
	1.953	$M_{2.5}$						
	1.958	M_2						
	1.962	W. M.						
Nov. 4...	1.948	$M_{1.01}$	S....	.871	.628	.17	12	Distant cirri around sky. Bright around sun.
	1.952	$M_{1.01}$						
	1.957	$M_{1.01}$						
	1.952	W. M.						
P. M.								
16...	1.907	$M_{2.91}$	U....	.867	.543	.21	11	Scattered cirri. Strong west wind.
A. M.								
16...	1.950	$M_{1.5}$	S....	.863	.486	.20	13	Earlier cirri, but sky very good during observations.
	1.941	$M_{1.36}$						
	1.940	$M_{1.30}$						
	1.944	W. M.						
17...	1.950	E_0	E....	.874	.649	.17	16	Good sky.
	1.974	$M_{2.5}$						

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. ρ/ρs. c.	Humidity. V. P.	Humidity. Relative humidity.	Remarks.
1921							*Per cent.*	
A. M.	*cal.*					*cm.*		
17...	1.939	M_2						
	1.962	$M_{1.5}$						
	1.962	W. M.						
18...	1.936	E_0	E....	0.881	0.665	0.25	20	Very good sky.
	1.934	$M_{2.5}$						
	1.945	M_2						
	1.945	$M_{1.5}$						
	1.940	W. M.						
19...	1.891	E_0	VG+.	.872	.690	.15	14	Cloudless. Little haze.
	1.945	$M_{2.5}$						
	1.952	M_2						
	1.938	$M_{1.5}$						
	1.937	W. M.						
20...	1.955	$M_{2.5}$	S....	.875	.678	.21	16	Good sky.
	1.963	M_2						
	1.955	$M_{1.5}$						
	1.958	W. M.						
21...	1.950	E_0	E....	.872	.675	.28	24	Much low haze. Cirr in west at end.
	1.963	$M_{2.5}$						
	1.957	M_2						
	1.950	$M_{1.5}$						
	1.955	W. M.						
23...	1.906	E_0	VG+.	.880	.775	.19	13	Cirri delayed start, and may have affected early bolographs.
	1.934	M_2						
	1.946	$M_{1.5}$						
	1.932	W. M.						
P. M.								
24...	1.956	$M_{2.5}$	S−...	.871	.744	.17	9	Considerable scattered cirrus.
	1.973	$M_{2.21}$						
	1.962	W. M.						
A. M.								
25...	1.954	E_0	E....	.879	.770	.17	18	Good sky.
	1.921	$M_{2.5}$						
	1.945	M_2						
	1.944	$M_{1.5}$						
	1.944	W. M.						
26...	1.943	E_0	E+..	.872	.607	.24	27	Good sky, but some haze and distant cirrus.
	1.951	$M_{2.5}$						
	1.948	M_2						
	1.950	$M_{1.5}$						
	1.948	W. M.						
27...	1.949	M_2	S....	.874	.669	.28	23	Some cirri, but none near sun.
	1.961	$M_{2.13}$						
	1.957	$M_{1.5}$						
	1.956	W. M.						
28...	1.967	$M_{1.61}$	S....	.806	.664	.20	19	Considerable cirrus, but none near sun during observations.
	1.960	$M_{1.23}$						
	1.963	W. M.						
29...	1.951	$M_{1.72}$	S....	.855	.631	.27	21	Considerable thin cirrus but not interfering. Sky rather mottled.
	1.941	$M_{1.00}$						
	1.946	W. M.						
Dec. 1...	1.907	$M_{1.35}$	S....	.869	.639	.33	29	No clouds near. Rather hazy.
	1.958	$M_{1.42}$						
	1.902	W. M.						
2...	1.952	E_0	E+..	.872	.660	.40	48	Good sky.
	1.940	$M_{2.5}$						
	1.941	M_2						
	1.945	$M_{1.5}$						
	1.944	W. M.						
3...	1.935	$M_{2.12}$	S....	.873	.684	.24	22	Good sky. Rather hazy.
	1.949	$M_{1.83}$						
	1.953	$M_{1.5}$						
	1.946	W. M.						
4...	1.950	$M_{2.33}$	S....	.873	.647	.23	22	Good sky.
	1.957	M_2						
	1.952	$M_{2.5}$						
	1.953	W. M.						
5...	1.946	$M_{2.5}$	S....	.880	.812	.17	14	Do.
	1.951	M_2						
	1.964	$M_{1.5}$						
	1.953	W. M.						
6...	1.929	$M_{2.5}$	S....	.878	.806	.20	16	Do.
	1.946	M_2						
	1.952	$M_{1.5}$						
	1.945	W. M.						
7...	1.964	$M_{1.42}$	S....	.873	.725	.23	16	Scattered cirri delayed start.
	1.972	$M_{1.31}$						
	1.968	W. M.						
8...	1.980	$M_{1.19}$	S−...	.863	.587	.30	20	Considerable scattered cirrus. Rather hazy.
	1.960	$M_{1.15}$						
	1.970	W. M.						
9...	1.973	E_0	E....	.874	.674	.23	24	Good sky; some haze.
	1.945	$M_{2.5}$						
	1.958	M_2						
	1.961	$M_{1.5}$						
	1.950	W. M.						
10...	1.931	$M_{2.5}$	U+..	.870	.651	.32	27	Cirri in east early, and forming near sun at end. Rather hazy.
	1.936	M_2						
	1.956	$M_{1.5}$						
	1.947	W. M.						
11...	1.940	$M_{2.22}$	S....	.859	.534	.44	31	Cirri around horizon but none near sun. Hazy.
	1.949	$M_{1.28}$						
	1.953	$M_{1.5}$						
	1.947	W. M.						
14...	1.913	$M_{2.5}$	S....	.880	.522	.27	21	Cirri all around horizon; also appearing near sun at end.
	1.928	M_2						
	1.938	$M_{1.5}$						
	1.926	W. M.						

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The mean monthly pressure as observed at land stations on the coast of the Atlantic varied considerably as compared with the normal at different localities. Large positive departures were the rule in the Azores and south coast of Ireland; these conditions were reversed at Newfoundland and Canadian stations, while the pressure was not far from the normal along the Atlantic and Gulf coasts of the United States, as well as in the Bermudas.

Days on which fog occurred was somewhat below the normal over the Grand Banks and the steamer lanes, and also in the vicinity of the British Isles, except that in the latter locality it was reported frequently during the first decade of the month.

As shown on the Pilot Chart more gales are usually encountered on the North Atlantic in December than in any other month, with the exception of January, and the difference between the two months is slight. The month under discussion was no exception to the general rule, except that the storm area of a number of the disturbances extended considerably farther south than usual.

On the 1st St. Johns, N. F. was the center of a well-developed LOW; the barometer at that station read 28.86 inches, while westerly and northwesterly gales prevailed as far south as the thirty-fifth parallel, as shown by the following storm log:

American S. S. *Saugerties:*

Gale began on the 1st, wind SW. Lowest barometer 29.87 inches at 1 p. m. on the 1st, wind SW., at latitude 34° 31′ N., longitude 46° 56′ W. End on the 3d, wind N. Highest force of wind 8, SW.; shifts SW.–W.–NW.

On the 1st there was also a disturbance of less intensity central about 8° west of the coast of Spain. Storm log follows:

French S. S. *Espagne:*

Gale began on the 1st, wind NW. Lowest barometer 29.65 inches at noon on the 1st, wind NW., 8, at latitude 40° 03′ N., longitude 18° 28′ W. End on the 2d, wind W. Highest force of wind 8, NW.; steady from NW.

Both of these depressions moved rapidly eastward and on the 2d the center of the western was somewhere near latitude 50° N., longitude 40° W., while the eastern LOW was over continental Europe.

Comparatively quiet weather prevailed until the 5th when a disturbance was central near Cape Sable and westerly gales covered the region as far south as the Bermudas. The northeastward movement of this LOW was very rapid, as on the 7th the center was not far from Iceland. Storm logs follow:

American S. S. *Saugerties:*

Gale began on the 5th, wind SW. Lowest barometer 29.64 inches at 4 p. m. on the 5th, wind SW., at latitude 40° 46′ N., longitude 62° 43′ W. End on the 5th, wind NW. Highest force of wind 9, SW.; steady from the SW.

American S. S. *Eastern Leader:*

Gale began on the 5th, wind, E. Lowest barometer 28.00 inches at 4 p. m. on the 5th, wind NW., 12, at latitude 46° 38′ N., longitude 53° 04′ W. End on the 6th, wind WSW. Highest force of wind 12, NW.; shifts SE.–SW.–NW.

British S. S. *Maraval:*

Gale began on the 5th, wind NW. Lowest barometer 29.50 inches at 3.30 a. m. on the 5th, wind W, 8, at latitude 32° 46′ N., longitude 69° 50′ W. End on the 6th, wind WNW. Highest force of wind 9; shifts SW.–W.

Swedish S. S. *Stockholm:*

Gale began on the 7th, wind SSE. Lowest barometer 29.15 inches at 8 a. m. on the 7th, wind S., at latitude 57° 10′ N., longitude 26° 30′ W. End on the 9th, wind WSW. Highest force of wind 10; shifts SSE.–S.–SW.–W.

Charts IX, X, XI, and XII show the conditions on December 9th, 10th, 11th, and 12th, respectively. On the 10th and 11th unusually heavy weather was encountered over the greater part of the steamer lanes, while on the latter date gales were also reported in the region between the Bermudas and the American coast. Storm logs follow:

American S. S. *Storm King:*

Gale began on the 9th, wind N. Lowest barometer 28.90 inches at 8 p. m. on the 10th, wind W., at latitude 47° 15′ N., longitude 41° 45′ W. End on the 11th, wind NW. Highest force of wind 10; shifts SSW.–NW.

Italian S. S. *Maria:*

Gale began on the 9th, wind SW. Lowest barometer 29.60 inches at 8 a. m. on the 10th, wind SSW., 9, at latitude 32° 20′ N., longitud, 51° 34′ W. End on the 10th, wind NW. Highest force of wind 9 SSW.; shifts S.–SSW.–W.–NW.

American S. S. *Wm. G. Warden:*

Gale began on the 10th, wind NE. Lowest barometer 29.88 inches on the 10th, wind NE., 9, at latitude 29° 41′ N., longitude 79° 43′ W. End on the 11th, wind NW. Highest force of wind 9, NE.; shifts NE.–NW.

American S. S. *W. M. Burton:*

Gale began on the 11th, wind SSE. Lowest barometer 28.38 inches at 2 p. m. on the 11th, wind NW., 11, at latitude 55° 20′ N., longitude 31° 30′ W. End on the 12th, wind NW. Highest force of wind 11, NW.; shifts SSW.–W.–NW.

American S. S. *Eastern Dawn:*

Gale began on the 11th, wind E. Lowest barometer 28.10 inches at 4 p. m. on the 11th, wind ENE., at longitude 40° 18′ N., longitude 61° W. End on the 12th, wind NW. Highest force of wind 12, NNW.; shifts NE.–NW.

The disturbance shown on Chart XII in the vicinity of Nova Scotia on the 12th moved but little during the next 24 hours, gradually filling in, although on the 13th southwesterly gales prevailed over a large section of the steamer lanes. Steamer logs follow:

British S. S. *Lexington:*

Gale began on the 11th, wind E. Lowest barometer 28.23 inches at 10 a. m. on the 12th, wind SE., at latitude 45° 09′ N., longitude 56° 08′ W. End on the 12th, wind SW. Highest force of wind 11; shifts SW.–W.

British S. S. *Valemore:*

Gale began on the 12th. Lowest barometer 29.40 inches at 4 p. m. on the 12th, wind S., 8, at latitude 48° N., longitude 44° 49′ W. End on the 13th, wind W. Highest force of wind 9, S.; veered very slowly.

Danish S. S. *Oscar II:*

Gale began on the 13th, wind SSW. Lowest barometer 29.67 inches at 6 a. m. on the 14th, wind WNW., 8, at latitude 56° 55′ N., longitude 16° 20′ W. End on the 14th, wind NW. Highest force of wind 9, WNW.; steady from WNW.

On the 16th there was apparently a disturbance near Iceland, although not enough reports were received to determine accurately its extent or position. Storm log follows:

Norwegian S. S. *Foldenfjord:*

Gale began on the 16th, wind SW. Lowest barometer 29.40 inches at 1 p. m. on the 16th, wind WSW., 12, at latitude 56° 07′ N., longitude 29° 20′ W. End on the 17th, wind WNW. Highest force of wind 12, WSW.; shifts SW.–WSW.–WNW.

On the 17th a LOW of very limited extent was central near latitude 45° N., longitude 40° W. A remarkable

feature of this disturbance was the fact that a number of vessels near the center encountered moderate winds, while the British S. S. *Vasconia*, near by, reported a strong southerly gale, as shown by the following storm log:

Gale began on the 17th, wind N. Lowest barometer 29.64 inches at 3 p. m. on the 17th, wind NNW., at latitude 46° 49′ N., longitude 40° 48′ W. End of gale on the 18th, wind N. Highest force of wind 11; shifts NNW.–N.

On the 17th westerly gales were reported by land stations on the British Isles, the storm area apparently extending as far west as the 25th meridian. Storm log follows:

Danish S. S. *United States:*

Gale began on the 16th, wind SW. Lowest barometer 29.78 inches at noon on the 16th. Wind SW., 8, latitude 53° 03′ N., longitude 33° 09′. End on the 17th, WNW. Highest force of wind 9, W.; shifts SW.–W.

From the 19th to the 23d heavy weather was the rule in the vicinity of the British Isles. On the 20th gales swept over the steamer lanes from Newfoundland to the coast of Europe. On the 21st the storm area covered a narrow strip between the 10th and 35th meridians and by the 22d it had contracted still farther, as on that date only a few vessels near the fiftieth parallel, between England and the twentieth meridian reported westerly gales. Storm logs follow:

British S. S. *Celtic:*

Gale began on the 19th, wind SSW. Lowest barometer 29.54 inches at 10 a. m. on the 19th, wind SSW., at latitude 51° 14′ N., longitude 15° 35′ W. End at midnight on the 19th, wind WNW.

French S. S. *La Lorraine:*

Gale began on the 19th, wind SW. Lowest barometer 29.65 inches at noon on the 21st, wind NW., 8, at latitude 49° 30′ N., longitude 30° 44′ W. End on the 21st, wind NW. Highest force of wind 12, shifts not given.

On the 22d Newfoundland was again the center of a severe disturbance, with strong northwesterly gales in the southerly quadrants. The LOW apparently moved rapidly northeastward during the next 24 hours, although it was impossible to plot its position accurately on the 23d, on account of the lack of observations. Storm logs follow:

British S. S. *Vasconia:*

Gale began on the 21st, wind S. Lowest barometer 29.20 inches at 4 a. m. on the 22d, wind WSW., at latitude 42° 24′ N., longitude 61° 40′ W. End on the 22d, wind NNW. Highest force of wind 11; shifts W.–WNW.–NW.

British S. S. *Burgondier:*

Gale began on the 22d, wind W. Lowest barometer 29.58 inches a 9 a. m on the 22d, wind W., 10, at latitude 43° N., longitude 56° 15′ W. End at midnight on the 22d. Highest force of wind 11; shifts. W.–NW

Dutch S. S. *Newyork:*

Gale began on the 23d, wind SSW. Lowest barometer 29.70 inches at 2 p. m. on the 23d, wind W. 8, at latitude 54° 28′ N., longitude 30° 40′ W. End on the 24th, wind W. Highest force of wind 10; shifts SSW.–SW.–W.

From the 24th to the 27th the conditions were comparatively featureless, although a few reports were received from vessels in widely scattered localities that encountered gales during this period.

From the 28th to the 31st a LOW remained in the vicinity of Nova Scotia, the storm area varying considerably from day to day, as on the 29th it extended to mid-ocean, while on the other dates it was restricted more to the western portion of the steamer lanes. Storm logs follow:

British S. S. *Osconian:*

Gale began on the 28th, wind SSE. Lowest barometer 29.33 inches at noon on the 28th, wind SSE., 7, at latitude 43° N., longitude 54° 47′ W. End on the 29th. Highest force of wind 10; shifts SSE.–WNW.

British S. S. *Huronian:*

Gale began on the 28th, SSW. Lowest barometer 29.48 inches at 4 p. m. on the 29th, wind WSW., 8, at latitude 50° 06′ N., longitude 33° 26′ W. End on the 29th, wind WNW. Highest force of wind 10; shifts SSW.–WSW.

Italian S. S. *Milazzo:*

Gale began on the 29th, wind NW. Lowest barometer 29.54 inches on the 29th, wind NW., 10, at latitude 34° 19′ N., longitude 67 W. End on the 30th, wind NW. Highest force of wind 10, NW., steady from NW.

British S. S. *Gloria de Larrinaga:*

Gale began on the 30th, wind S. Lowest barometer 29.29 inches at 4 p. m. on the 30th, wind S., 8, at latitude 37° 20′ N., longitude 52° 45′ W. End on the 31st, wind NW. Highest force of wind 8; shifts not given.

British S. S. *Osconian:*

Gale began on the 30th, wind SSE. Lowest barometer 29.14 inches at 10 a. m. on the 30th, wind NNW., 9, at latitude 41° 22′ N., longitude 63° 06′ W. End on the 31st, wind N. Highest force of wind 11; shifts SSE.–WNW.–N.

American S. S. *Vacuum:*

Gale began on the 29th, wind NNW. Lowest barometer 29.88 inches at 2:30 p. m. on the 29th, wind NNW., 5, at latitude 35° 50′ N., longitude 75° 12′ W. End on the 30th, wind W. Highest force of wind 9, NNW.; steady from NNW.

From the 28th to the 30th there was a disturbance near the British Isles, with westerly gales over a limited area. Storm log from British S. S. *Turcoman* follows:

Gale began on the 29th, wind S. Lowest barometer 30.04 inches at 2 a. m. on the 30th, wind SW., 10, at latitude 51° 12′ N., longitude 19° 40′ W. End on the 30th, wind WNW. Highest force of wind 11, SW.; shifts SSW.–SW.–WSW.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Pressure was considerably below normal in the Aleutian region until the 14th, and a series of depressions moved eastward or southeastward across Bering Sea and the Gulf of Alaska, causing almost constant gales over the eastern portion of the trans-Pacific steamer lanes. On the 2d the barometer at Kodiak fell to 28.30, and on the 7th a reading of 28.80 was reported from Dutch Harbor.

Commencing about the 14th pressure rose rapidly over the Aleutian area and Alaska. At Dutch Harbor the barometer on the 16th was 30.56 inches, about 1 inch above normal, and at Tanana, in interior Alaska, 31.18 inches. In connection with this general pressure change depressions developed in both the eastern and western portions of the ocean.

As early as the 13th there were evidences of a depression between the Hawaiian Islands and the California coast. During the several days succeeding that date there was very little change observed in its position. On the 17th and 18th, however, it moved to the coast, where it remained until the 22d, then passing inland but leaving a fresh depression forming to the westward.

In the western portion of the Pacific three depressions moved eastward from Asiatic coastal regions during the early days of the month, the most important being one that was central near Nemuro on the 2d (Eastern time) with a central isobar of 29.29 inches.

On the 4th a typhoon appeared to the south of Guam, moving northwestward. According to the *Weekly*

Weather Report of the Imperial Marine Observatory at Kobe, the westward advance of this typhoon was checked by a strong anticyclone over Mongolia and its course was changed to the northeastward. The center passed to the southeast of the Bonin Islands on the 9th.

From the 15th to the 24th pressure was low at Honolulu, and during this period a poorly defined depression moved eastward in the latitude of the Hawaiian Islands. By the morning of the 25th it had developed into an energetic storm and was encroaching upon the California coast, where phenomenally heavy precipitation occurred during the last week of the month. At the same time fresh depressions were moving eastward across Bering Sea and gales were being experienced by vessels in mid-ocean.

As a result of the long stormy period that prevailed over the northeastern portion of the Pacific during the last part of November and the first part of December an unusual and altogether unpleasant experience fell to the lot of the American S. S. *Eldridge*. This vessel under command of Capt. F. W. Brooks, Observer E. J. Stull, sailed from Seattle on November 19, just in time to become involved in the severe storm that prevailed on the Oregon and British Columbian coasts on the 21st. From that time on until December 19, when her report ends, the *Eldridge* experienced no less than nine distinct gales. Winds as high as force 11 were recorded on four occasions. The lowest barometer was 28.67 inches. This was recorded at 7:45 p. m. on December 6, in 42° 18′ N., 165° 35′ W. Fifteen minutes later the vessel was in the "eye" of the storm. Mr. Stull states that there was a huge sea, the waves being estimated to have a height of 35 to 45 feet and a length of 550 feet.

Gales were of frequent occurrence throughout the month along the principal steamer routes. Generally they were from a westerly or southerly direction, the centers of the depressions which gave rise to them keeping well to the northward. Second Officer G. Clarke of the British S. S. *Empress of Japan*, which made the voyage from Yokohama to Vancouver between the 2d and 12th, stated in his report that average weather for the season prevailed between those dates. The *Empress of Japan* experienced fresh gales from the northwest and north, with high seas. The weather was mostly clear, with occasional light snow squalls. On the 7th, when in 46° 57′ N., 169° 30′ E., the barometer fell to 28.55 inches.

The Swedish sailing yacht *Fidra*, Capt. Tamm, bound from Suva, Fiji Islands, to Yokohama, was involved in a gale on the 29th and 130th (Eastern time) in 32° 35′ N., 141° 30′ E. According to Observer N. van Ryswijk, the gale began at SW. and by 8 a. m. of the 29th had reached force 9, SW. It continued to increase in strength until 5 a. m. of the 30th, when it was blowing with force 12, WNW. By 8 a. m. of the same day it had decreased to force 7, WNW. The lowest barometer recorded was 29.68 inches, at noon of the 29th.

For the month as a whole pressure was above normal by approximately 0.06 inch at Dutch Harbor and 0.02 inch at Midway Island. At Honolulu it was practically normal.

TROPICAL HURRICANE OF SEPTEMBER 5–15, 1921.

In the September issue of the REVIEW there were several references to a hurricane that appeared to the southeast of Bermuda on September 12. This hurricane traveled northeastward across the North Atlantic and was last observed on the morning of the 15th in 53° N., 35° W.

It was thought at first that this tropical cyclone formed in the region immediately to the eastward of the Bahamas about September 10 but from later advices it appears that it was in existence as early as the 5th and on that date was probably near 22° N., 54° W.

The earliest information regarding it is contained in a report by Second Officer A. C. Bos, of the Dutch S. S. *Neptunus*, as follows:

> Monday, the 5th of September coming from Amsterdam and bound for St. Thomas, we had different apparitions that showed the approach of a hurricane.
>
> Being on 25° 11′ N. and 55° 50′ W., we had a gentle southeasterly breeze, increasing that afternoon to a strong breeze from the NE. About 10 o'clock p. m. (G. M. T.) the sky was overcast, the sea rough with easterly swell and it lightened in a southerly direction. Our barometer, indicating 764.1 mm. (30.08 inches) at 8 o'clock, continued falling. The course was S. 48 W. (true).
>
> At 11 o'clock, the wind was 7–8 then, we heaved and went slowly to the NE. (barometer 763.7 cm., 30.07 inches). After that the wind became ESE. and abated a little; at midnight (about 4 o'clock G. M. T.), we had a strong breeze, still ESE., the sky was rather clear and we continued our voyage.
>
> Toward daybreak the wind increased and the sky became overcast again; at 12 o'clock, the wind was then ESE., the sea high with a heavy southerly swell and the barometer did not rise, we went full speed NE. Again the wind abated by little and little, the sea became better and as the barometer got its regular process, we steered at 6 o'clock p. m. once more S. 48. W. and reached St. Thomas the 9th of September where they expected a storm.
>
> The 7th and 8th of September we had a fresh or moderate breeze (SE. to SSE.) and observed nothing particular.

The Dutch S. S. *Noorderdijk*, Capt. A. B. Jochems, Rotterdam for Colon, was under the influence of the hurricane on the 7th and 8th, the center evidently passing across her bow on a west by north course at a distance of perhaps 150 miles. At 8 a. m. of the 7th, when in 25° 56′ N., 60° 16′ W., the wind was ESE., force 6, cloudy sky, rough sea, moderate ESE., swell, barometer 29.98. At 4 a. m. of the 8th the wind had increased to a fresh ESE. gale. By 8 a. m. it had shifted to SW. and moderated to a strong breeze. The sky was cloudy. There was a high SE. swell, shifting and decreasing to a light SW. swell. Much rain fell during the day. At 7:46 a. m. of the 8th, the *Noorderdijk* was in 23° 14′ N., 63° 28′ W. At that hour the wind was SW., 7, barometer 29.83 inches.

The next vessel to become involved was the British S. S. *Camito*, Capt. J. H. Scudamore, Avonmouth for Kingston, calling at Grand Turk, Bahamas. It was thought at first that the *Camito* had been in the center of the hurricane but Capt. Scudamore states that this information was incorrect. His report is as follows:

> On Friday, September 9, the barometer commenced to fall at 6 a. m.; there was a light ESE. wind, weather fine and clear, barometer 30.13. Between 8:30 and 10:30 a. m. very heavy rains squalls, wind variable and light, hauling to south, barometer 30.11. Noon. Position 25° 30′ N., 63° 23′ W. Overcast, clouds breaking to southwest, very green shadows close to horizon. 3 p. m., wind S. by E., force 6, barometer 30.00, sea rough and increasing, continual heavy rain squalls. 8 p. m. strong S. by E. breeze, rough sea, barometer steady though pumping. Midnight, wind S., barometer 29.98, continuous heavy rain.
>
> September 10, 4 a. m., wind S., force 8, occasional rain squalls, barometer 29.96. 5 a. m., wind shifted to SW., clearing at times, squally, rough sea. 8 a. m., light SW. breeze, slight swell, cloudy and clear, barometer 30.05.

A revised track of this hurricane is shown in figure 1, p. 658, this REVIEW.—*F. G. T.*

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

The feature of the month which seems of greatest importance was the change which took place on the 18th from the dry to the wet type of weather for California. The rains in that State continued during the remainder of the month, being unusually heavy in the southern portion. Elsewhere in the United States with the single exception of the Lake region precipitation was deficient.

Temperature was below normal in New England and the extreme Northwest; elsewhere it was in excess by from 1° to 6°.

The storm of the 18th–19th in the Lake region was attended by winds of hurricane force.

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

Low pressure areas were not so numerous as during the preceding month, but included some very severe storms off the North Atlantic coast, over the region of the Great Lakes, and during the third decade off the Pacific coast. Both the Alberta and South Pacific types greatly exceeded the normal. However, the South Pacific type did not make its appearance until after the disintegration of the great plateau HIGH which persisted during the first half of the month. High pressure areas were about normal as to type and rather strongly developed, as they usually are at this season.

Tables showing the number of HIGHS and LOWS by types follow:

LOWS.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf	South Atlantic.	Central.	Total.
December, 1921..	9.0	1.0	5.0	1.0	1.0	1.0	1.0	.....	.....	19.0
Average number 1892-1912 inclusive.....	4.3	2.5	0.8	0.3	1.1	2.5	0.2	0.3	0.4	12.4

HIGHS.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain Region.	Hudson Bay.	Total.
December, 1921.....	3.0	1.0	6.0	.....	1.0	11.0
Average number, 1892-1912 inclusive	1.1	1.2	4.7	1.3	0.5	8.8

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, February 1, 1922.]

PRESSURE AND WINDS.

During the first half of the month high atmospheric pressure was maintained almost constantly over the Plateau region and the far Northwest, the average for this period being far above the normal and at points the highest pressures ever observed were recorded near the first of the month. At the same time storm areas from the Pacific that usually enter the United States over the far Northwest were forced northward into the British possessions, moving thence southward into the United States east of the Rocky Mountains, and thence to the Atlantic coast. Some of these storms developed considerable energy in the region of the Great Lakes and further eastward, with the result that the average pressure during the first half of the month was less than normal over most central and eastern districts.

By the middle of the month high pressure had developed over the eastern portion of the country, the far western HIGH that had persisted so long showed signs of breaking up, and storm areas began to enter the United States at lower latitudes, with resultant heavy rains in California reaching to the southern extremity of the State.

During the latter half of the month strong anticyclonic areas entered the Missouri Valley States from the adjoining British Provinces in rapid succession, and moving eastward over the central valleys to the Atlantic coast dominated the weather from the Rocky Mountains eastward. During this period pressure remained low over the Pacific Coast States, particularly over the far Southwest, where heavy rains, high winds, and flood conditions were reported.

For the month as a whole, pressure averaged less than the normal over all districts from the Mississippi River eastward, although the departures were usually small. Over the Great Plains, Rocky Mountain regions, and the far Northwest, as well as in the western Canadian Provinces, the average pressure was above normal, while over California and the adjacent portions of the Plateau the averages were below normal.

The prevailing winds were variable to an unusual degree, but in the main they were from north to west points over the Great Plains, upper Mississippi Valley, Lake region, and Northeastern States, and from southerly points in the Ohio and lower Mississippi Valleys, and portions of the Gulf States.

High winds occurred over extensive areas and wide property damage resulted, particularly in connection with the storm over the Great Lakes and districts to the eastward on the 17th and 18th.

TEMPERATURE.

December on the whole was a warm month, only small areas in the extreme Northeast and the far Northwest having averages below the monthly normal. The month was distinctly warm in the southern portions of the country and over the Dakotas, where the average excess was about 6°, and at a few points in the Southeastern States the monthly averages were the highest of record for December.

The first half of the month had few important temperature changes, and generally mild weather for the season of the year prevailed in most districts.

About the 16th considerably colder weather overspread the Plateau and Rocky Mountain districts and during the following few days extended rapidly eastward and southeastward, bringing the coldest weather of the month over many far western districts and the southern portions of the country as far east as the Middle Gulf States. Another period of moderately cold weather

prevailed over the northern districts from Montana eastward during the 20th to 22d, at which time the coldest weather of the month was experienced in portions of the Great Lakes region, the Ohio Valley, and Middle Atlantic States. This was quickly followed by a high barometric pressure area from the British Northwest Provinces, attended by the coldest weather of the month about Christmas over much of the country between the Rocky Mountains and the Mississippi River. The lowest temperature reported during the month, 41° below zero, at a point in Minnesota, occurred at this time.

The principal warm period of the month was from the 12th to 14th, when unusually high temperatures prevailed in the central valleys and far western districts. The maximum temperatures during this period were the highest of record for December at many points in the Great Plains region.

The continued warmth during the month over the Gulf States caused fruit trees in some sections to blossom, and it is reported by the Weather Bureau official at Due West, S. C., that a second crop of cherries ripened on several trees at that place, and well-developed apples of good flavor were picked and eaten.

PRECIPITATION.

On the whole the month had mostly deficient precipitation, particularly over the Atlantic and Gulf Coast States, the Great Plains, and far Northwest. There was a moderate excess in the States of the Ohio Valley and thence northward, and generally in the Rocky Mountain region, the central Plateau, and the far Southwest. The amounts received in southern California were far in excess of the usual fall.

The periods of extensive precipitation were the 1st to 3d, from the Southern Plains northeastward and eastward to the Atlantic, with heavy falls in eastern Texas and portions of the Mississippi Valley and Gulf States; on the 8th to 10th, when considerable areas in the Gulf States had substantial rains; on the 11th to 13th, when unusually heavy rains occurred in the far Northwest; on the 16th to 19th, when rain or snow prevailed in practically all districts from the Great Plains eastward, the rain being moderate to heavy over portions of the Middle Gulf States, the upper Mississippi Valley, and Great Lakes region.

At the end of the second and the first few days of the third decade there were unusually heavy rains in southern California, and more or less rain or snow occurred over large areas of the Pacific Coast and Plateau States. About the 23d rain set in over the central valleys, and during the following two days extended into most eastern districts, with heavy falls in portions of the middle Mississippi and lower Ohio Valleys. Heavy rains again occurred over California and other portions of the far Southwest on the 26th and 27th.

The excessive rains in southern California caused much damage to property, and landslides in the State of Washington, due to heavy rains, caused the death of 10 or more persons. At the end of the month severe drought prevailed in portions of southern Florida and over the western portions of the southern Great Plains.

SNOWFALL.

In the regions from the Rocky Mountains eastward snowfall occurred over about the usual areas, but as a rule the amounts were light and less than normal. Rather heavy falls occurred over small areas in the mountains of Virginia, West Virginia, Maryland, and Pennsylvania, and depths of 5 to 10 inches or more had accumulated by the end of the month in the upper Lake region and northern New England.

In the western mountains no unusual falls were reported, and over the northern and central portions favorable reserves appeared to have accumulated in the high ranges. In the southern mountain districts the falls were usually light, and the stored reserves even at the highest elevations were far from encouraging.

RELATIVE HUMIDITY.

Sharp variations in the average relative humidity were observed, and positive and negative departures from the normal showed wide fluctuations over short distances. Notable instances are found in the middle Rocky Mountains where positive departures ranged from 8 to 14 per cent, while in the adjacent Southern Plains, negative departures of from 10 to 25 per cent occurred. At Phoenix, Ariz., the average relative humidity at 5 a. m. was 4 per cent below normal, while at Yuma in the same State it was 12 per cent above.

Generally speaking, the areas of heavy and light precipitation are fairly well outlined by the positive and negative departures of the relative humidity from the normal.

Severe local storms.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
Seattle and western Washington.	13			11		Landslides and rain.	No property damage reported	Washington Herald (Washington, D. C.).
Pittsburgh, Pa.	17					Wind and rain	Much damage caused to wires, plate glass, etc. Traffic and electric light and power operations interfered with.	Official, United States Weather Bureau.
Greenwood, S. C., and vicinity.	17	p. m.				Wind	One person injured and some buildings and trees damaged.	Greenville News (Greenville, S. C.).
Milwaukee, Wis., and vicinity.	17					Wind and snow	Lake traffic delayed and telephone service interfered with. Several accidents reported.	Journal (Milwaukee, Wis.).
Alpena, Mich.	17-18					Ice	All overhead wire systems impaired, forest trees bent to ground. Ice covering on ground so great and continued so long that small game and birds were deprived of food.	Official, United State Weather Bureau.
New York (central and western sections, especially Buffalo).	17-18			2	$1,500,000	Wind	Severe damage to shipping. Dwellings on lake front, docks and piers destroyed. Boats stranded, telephone and telegraph lines impaired, electric light and car service badly crippled. Houses and barns unroofed. Numerous persons injured.	New York Herald (New York, N. Y.).
Wellsboro, Pa.	18	a. m.				do	General damage done.	Wellsboro, Pa.
New York City, N. Y. (The Bronx).	18					do	Severe general damage	New York Tribune (New York, N. Y.).
Sunbury, Pa. (Northumberland and adjoining counties).	18					do	Heavy damage to lines of communication; roofs and trees suffered.	Herald (New York, N. Y.).
Linden, N. J.	18				30,000	do	Two houses damaged; sheds and garages destroyed; 3 persons injured.	The World (New York, N Y.)
Lone Pine, La.	19			1		do	School house and 3 dwellings destroyed, other buildings damaged; several injured.	Post (Chicago, Ill.).
Illinois (central portion)	22-23				150,000	Ice	Much damage to overhead electrical systems	Official, United States Weather Bureau.
Tennessee (near Phelan, Tipton County).	23				20,000	Tornado	Considerable property damaged; 2 injured	Do.
Arkansas (near Clarkedale)	23	p. m.	166	6	150,000	do	Number of buildings wrecked, gin, warehouses, residences, etc.; 15 persons seriously injured.	Do.
Northeastern Louisiana (Union and Morehouse Parishes).	24	12:30 a. m.	200	2	60,000	do	Nearly all buildings in Spencer destroyed, 20 box cars demolished, timber damaged; many persons injured.	Do.
California (central and southern portion).	18-27			4	2,500,000	Wind and rain	Property damaged, communication disrupted, bridges washed away, vessels blown from moorings, considerable havoc caused along coast.	Post (Washington, D. C.).
Helena, Mont., and vicinity	30	a. m.				Wind	Minor damage	Record-Herald (Helena, Mont.).
Butte, Mont.	30	1:30 a. m.				do	General damage done	Do.
Milwaukee, Wis.	30-31					do	Caused considerable damage and seriously interfered with lake shipping.	Official, United States Weather Bureau.

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

Storm warnings.—A disturbance of marked intensity was central over eastern Iowa at 8 p. m. of the 1st, moving rapidly northeastward, and northwest storm warnings were ordered displayed at 10 p. m. on Lakes Superior and Michigan and southwest warnings on Lakes Huron, Erie, and Ontario. The next morning warnings were displayed on the Atlantic coast from Jacksonville, Fla., to Eastport, Me. These warnings were well verified on the Great Lakes and at a number of coast stations.

The next storm warnings were issued for the Atlantic coast from Cape Hatteras to Boston, Mass., at 1:30 p. m. of the 4th, when a disturbance was central over North Carolina and increasing rapidly in intensity.

On the evening of the 9th southwest storm warnings were displayed on Lakes Erie and Ontario in connection with a disturbance that was moving rapidly eastward over the northern Lake region.

At 8 a. m. of the 17th a disturbance of considerable intensity was central over southern Lake Michigan, moving east-northeastward, with a strong area of high pressure to the eastward. Southwest storm warnings were displayed at 11 a. m. on the Atlantic coast from Cape Hatteras to Eastport, Me., and on the east Gulf coast from Bay St. Louis, Miss., to Cedar Keys, Fla. Advisory warnings were also sent to open ports on Lake Michigan and forecasts of gales were included in the forecasts for States bordering on the Great Lakes. All warnings were fully verified. This storm increased greatly in intensity as it advanced over the Lake region and it was attended by strong gales, the wind velocity at Buffalo, N. Y., reaching 96 miles an hour from the southwest, equaling the highest ever before recorded (Dec. 23, 1920), and continuing extremely high for a much longer period than ever before. During the three hours from 9 a. m. to noon of the 18th, 268 miles were recorded, or an average velocity of 89.3 miles per hour, and from 5 a. m. to 5 p. m., 907 miles, or an average of 75.6 miles per hour. Property damage in Buffalo and vicinity due to this storm is estimated at from $1,000,000 to $1,500,000. Of the 62 vessels loaded with grain which were anchored beneath the break wall 27 were torn from their moorings and swept on to the beach and it is probable that a greater number of vessels would have been torn loose and damaged had it not been for the timely warnings disseminated from the Buffalo Office of the Weather Bureau. The Buffalo Commercial of December 19 says in an editorial:

> It is unlikely that there has been in years a storm of such sustained fury. That there was no greater damage to shipping is due, of course, to the fact that there was ample warning given by the Weather Bureau.

A disturbance that developed over the Lake region on the 20th moved rapidly eastward to the lower St. Lawrence Valley with a marked increase in intensity, and it was followed during the 21st by a decided increase in pressure and gales along the Middle Atlantic and North Atlantic coasts, for which warnings were issued on the morning of the 21st. Another storm of somewhat similar character was central over the lower St. Lawrence Valley on the morning of the 29th and northwest storm warnings were ordered for the Atlantic coast from Cape Hatteras

to Eastport, Me. A maximum wind velocity of 64 miles an hour was registered at New York, N. Y., and 56 miles at Block Island, R. I., Atlantic City, N. J., and Cape Henry, Va.

Another severe storm moved eastward over the Lake region during the 31st attended by gales throughout the Lake region and along portions of the Middle Atlantic and North Atlantic coasts. The highest velocity reported was 80 miles an hour from the southwest at Buffalo, N. Y. Ample warnings were issued in connection with this storm.

Cold-wave warnings.—No cold-wave warnings were issued or required, except for very limited areas, until the 21st, when a disturbance of considerable intensity over the North Atlantic States and the lower St. Lawrence Valley was followed by a decided increase in pressure and a marked fall in temperature over Ontario and the Lake region and cold-wave warnings were ordered for New England, New York, Pennsylvania, New Jersey, Delaware, Maryland, and the District of Columbia. These warnings were fully verified.

During the 23d–24th a disturbance moved rapidly eastward over the Lake region and the Northeastern States and it was followed by rapidly rising pressure and much colder weather, and cold-wave warnings were ordered for the Lake region, the Ohio Valley, Tennessee, the East Gulf States, northern New England, and northern and central New York. These warnings were only partially verified.

During the last two days of the month there was marked activity in the movement of areas of low and of high pressure accompanied by marked fluctuations in temperature over northern sections east of the Rocky Mountains. Cold-wave warnings were ordered for New England, New York, New Jersey, eastern Pennsylvania, and northern Michigan on the evening of the 28th and the morning of the 29th, and for northern Vermont and extreme northern New York on the evening of the 31st.

Frost warnings.—Frost warnings were issued on the following dates for portions of the South Atlantic and East Gulf States: 4th, 5th, 6th, 9th, 10th, 17th, 18th, 25th, 26th, and 31st. However, no frost warnings were issued for southern Florida during the month.—*C. L. Mitchell.*

CHICAGO FORECAST DISTRICT.

With the exception of advices issued to the stock interests in Nebraska and Wyoming on the morning of December 2, no special warnings were ordered from the Chicago Forecast District until the middle of the month. Following the storm which necessitated the issuance of stock warnings on the above date, the weather throughout the district until the 15th was dominated by an area of high pressure which persisted over the Plateau region, thus causing generally fair weather with temperature considerably above normal.

By the 15th, however, a depression had formed over the middle Rockies with much colder weather and high pressure to the north and northwest. On the 15th and 17th, cold-wave warnings were issued for portions of the northern Rocky Mountain region.

However, the first severe cold of the present season, accompanied by an area of strong high pressure, did not appear in the Northwest until the morning of the 18th and during the period from the 18th to 20th, spread slowly eastward and southward over the district, warnings being issued in advance in connection with its movement. Advices to stock interests in the northern Rocky Mountain region and the Plains States were issued on the 18th and 19th.

On the morning of the 22d another HIGH appeared in the Canadian Northwest and during the 23d and 24th moved eastward and southward, warnings during this period being issued only for the eastern portion of the district. On the 23d, stock advices were issued for Nebraska, Kansas, and southern Wyoming.

On the 28th cold-wave warnings were issued for eastern North Dakota and northern Minnesota, following the movement of a disturbance of moderate intensity across the northern Lake region.—*E. H. Haines.*

NEW ORLEANS FORECAST DISTRICT.

On December 1, southeast storm warnings were displayed from Port Arthur to Velasco, Tex., and small-craft warnings from Velasco to Brownsville, because of squally conditions in a trough of low pressure which extended from the upper Mississippi Valley to Texas. Another depression was centered over the Texas Panhandle on the p. m. map of the 2d and southeast storm warnings were ordered on the east coast of Texas. A large high-pressure area was moving down over Texas on the p. m. of the 3d, and northwest storm warnings were ordered for the Texas coast, Port Arthur to Velasco. These warnings were verified.

On the morning of the 8th, northwest storm warnings were displayed from Port Arthur to Velasco and small-craft warnings on the remainder of the Texas coast because of an area of high pressure advancing southeastward in the rear of a disturbance over Louisiana. Fresh winds prevailed during the day.

Small-craft warnings were displayed on the Louisiana and Texas coasts at 8:20 a. m. (Central Time), on the 17th, for strong northwest winds diminishing at night. The wind was already strong at the time the warning was issued and diminished during the afternoon.

Small-craft warnings were displayed on the Texas coast on the 23d, and northwest storm warnings were issued for the east coast of Texas at night on the 23d. The next morning the storm warning was extended over the remainder of the Texas coast and small-craft warnings were displayed on the Louisiana coast. Winds occurred as forecast.

Small-craft warnings were displayed on the Texas coast on the 31st and were justified.

Advices were issued on the 8th, 17th, and 25th, to interests represented in Tampico, Mexico, for strong northerly winds to moderate gales, and on the 25th for Progreso, Mexico.

Cold-wave warnings were issued at 8:40 p. m. of the 2d, for northwestern Arkansas, Oklahoma, and northern Texas, and were repeated next morning except for the northern portion of west Texas. The warning was fully verified in Oklahoma and at Abilene, Tex., and a decided fall in temperature occurred in the remainder of the territory warned.

Cold-wave warnings issued at 8:40 a. m. of the 16th, for Oklahoma and northwestern Texas, and on the 17th for Port Arthur, Tex., were justified.

Cold-wave warnings issued 8:45 p. m. on the 18th, for Oklahoma, were repeated and extended on the 19th to northwestern Arkansas and the northwest portion of east Texas, were repeated again at 8 p. m.; and on the 20th they were repeated, 9 a. m., and extended over Arkansas and the northern portion of east Texas; a coal wave occurred in Oklahoma, and much colder prevailed in other portions of the district covered by warnings.

Cold-wave warnings were issued for Oklahoma, 8:30 p. m. of the 22d, and repeated and extended to extreme northwestern Arkansas at 9 a. m. of the 23d, and were extended at 3 p. m. over Arkansas and the interior of Texas, and were repeated at 8:30 p. m. for Arkansas and Dallas and Palestine, Tex.; the warning was extended at 9 a. m. of the 24th to the coast; these warnings were generally justified.

Frost or freezing warnings were issued for portions of the southern part of the district on the 4th, 5th, 8th, 9th, 10th, 17th, 25th, and 31st. Fire-weather warnings were issued on the 3d, 19th, and 23d.—*I. M. Cline.*

DENVER FORECAST DISTRICT.

With the exception of a storm which appeared over Idaho on the afternoon of the 1st and moved rapidly southeastward across the district, the first half of the month was characterized by settled weather, under the influence of high pressure in the Plateau region. During the latter part of the month low pressure and unsettled weather prevailed west of the mountains, while a succession of cold anticyclonic areas occupied the northeastern slope.

The storm which appeared over Idaho on the afternoon of the 1st moved rapidly southeastward, overspreading both slopes of the Rocky Mountains by 8 a. m. of the 2d, with barometer readings more than 0.5 inch below the normal. The disturbance was followed by an unusually sharp rise in pressure in the North Pacific States. Warnings of a moderate cold wave were issued for Utah, northern and western Colorado, northern Arizona, and northwest New Mexico on the 2d. The temperature fell 10° to 16° in the greater part of Colorado and New Mexico and was well below the freezing point. The coldest weather following the storm did not occur, however, until the morning of the 4th, when the readings in the greater part of the area for which warnings were issued ranged from 2° to 14° above zero. An area of low barometer developed in the northern Rocky Mountain region on the 15th, being central at 8 p. m. in northeastern Colorado. Cold-wave warnings were issued for eastern Colorado. The warnings were justified, the prevailing temperatures ranging from zero to 14° above zero on the morning of the 17th. A cold wave also occurred in northeastern Arizona, extreme southwestern Colorado, and parts of New Mexico.

Another area of low pressure of considerable intensity appeared over Nevada on the 18th, with an area of high pressure over Alberta. Cold-wave and live-stock warnings were issued for eastern Colorado and extreme eastern New Mexico. Although the anticyclonic area moved very slowly southward and eastward, the western disturbance remained central on the Pacific coast, having apparently recurved to the northeastward before reaching the coast. While the falls in temperature were not great, colder weather prevailed in eastern Colorado, with temperatures ranging from 5° to 20° above zero on the mornings of the 19th and 20th. Unsettled weather, with local rain or snow, prevailed in Utah, western Colorado, and northern Arizona from the 18th to the 23d under the influence of this disturbance. On the evening of the 22d another cold anticyclonic area was overspreading the northeastern slope, while the western disturbance had apparently concentrated as a deep center of depression in southwestern Utah. Warnings of a cold wave were distributed for Utah, Colorado, northern Arizona, and northern and eastern New Mexico, and heavy snow for Utah, Colorado, northeastern Arizona, and northern New Mexico. Heavy snow occurred in parts of Utah and Colorado and a cold wave in the greater part of the area for which warnings were issued. Zero temperature was reported on the morning of the 24th at Flagstaff, and the temperature was 6° to 8° below zero in northeastern Colorado. A cold-wave warning issued for southeastern and extreme eastern New Mexico on the morning of the 24th was followed by a sharp fall in temperature with readings close to 20° above zero in southeastern New Mexico. Heavy snowfall warnings were issued for Utah and northern Arizona on the morning of the 25th, an area of unusually low pressure having appeared on the middle Pacific coast. The disturbance decreased in intensity, however, and failed to move inland. Moderate to heavy precipitation was confined to western and central Arizona.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

The pressure distribution controlling the weather over the Pacific Slope during December, 1921, was of two entirely different types, and each covered practically one-half of the month. During the first portion of the month the pressure was low over Alaska, the British possessions and the north Pacific Ocean and high over the southern Plateau, California, and the ocean to the west and storms from the north Pacific entered the continent at a high latitude. This is the typical distribution for fair weather in California and the Plateau, light rain in western Oregon and seasonable rain in Washington.

The latter part of the month presented a complete reversal of the pressure distribution. A large sluggish area of high pressure covered Alaska, the British possessions, North Pacific Ocean, and Rocky Mountain region, and caused storms from the ocean to be forced far south of their usual path and enter the continent through California. This is the typical condition for heavy precipitation over California and the Plateau. Hence, the first part of the month gave moderate precipitation in western Washington and northwestern Oregon, and the latter part heavy precipitation in California and the Plateau region.

The storm from the 18th to the 27th did a large amount of damage to highways, bridges, and railroads in southern California by floods, washouts, and landslides. The gale on the 25th in the San Francisco Bay section prostrated telegraph and telephone lines, uprooted many trees, unroofed several houses, and interfered with the ferry services on the bay. On the 20th, while about 900 miles off the California coast en route to Honolulu, the Japanese freighter, *Texas Maru*, was severely damaged by gales and high seas and the first and third officers were washed overboard.

Storm warnings were ordered 15 times, small craft 2, and advisory warnings 4. Frost warnings were issued in California 9 times and a cold-wave warning in eastern Washington and northern Idaho on the 18th.—*G. H. Willson.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

Mention of the Ohio River flood of late November and early December was made in the MONTHLY WEATHER REVIEW for November, but no data were given for points south of Mount Vernon, Ind.

The crest of the flood passed into the Mississippi River on December 8, but as the Cumberland and Tennessee Rivers contributed only relatively small volumes of water, there were no flood stages reached below the vicinity of Shawneetown, Ill. At this place, however, where the gauge heights showed the full effect of the Wabash and White Rivers floods, the crest stage was 39.6 feet, or 4.6 feet above the flood stage, on December 8. Farther down the river the crest stages were from 8 to 9 feet below the flood stages.

In the vicinity of Shawneetown there was a crop loss of about $5,000, while other crops and stocks to the value of $25,000 were saved by the warnings.

There was a second and more severe flood in the Ohio River during the last week of the month. It was caused by general and heavy rains from December 22 to 24, throughout the principal drainage area of the river, except the Cumberland and the Tennessee River districts. On December 24 and 25, there was a decided fall in temperature, and over the upper drainage area the rain changed to snow, thereby checking the rise in the river. As a result, flood stages were not reached above the mouth of the Great Kanawha River, Pittsburgh reporting 21.2 feet at 8 a. m., December 25, and Parkersburg 32 feet at 8 a. m., December 26.

There were, however, general floods in the rivers of West Virginia and eastern Kentucky, the crests ranging from 1 to 9 feet above the flood stages.

From the mouth of the Great Kanawha River to below Shawneetown, Ill., flood stages were general, except in the immediate vicinity of Louisville, Ky., the crest stages ranging from 2 to 9.3 feet above the flood stages, the latter in the vicinity of Shawneetown as a result of the considerable increment from the White River. It should be mentioned that the flood waters from the Licking River of Kentucky added from 3 to 4 feet to the Cincinnati crest of 56.1 feet. It is interesting also to note that the precipitation causing this flood was heaviest near the main stream and along the middle course, and comparatively light over the upper tributary basins, with a resulting flat crest over the middle section.

The floods in the Muskingum and lower Scioto Rivers were moderate and no damage was done, but the Hocking River flood was more marked, although with but little resulting damage.

The flood in the lower White River of Indiana was more pronounced, but owing to the lateness of the season and the timeliness of the warnings, little damage was done.

The Illinois River remained above the flood stage from Peru to Beardstown throughout the month, but the stages were not high enough to cause any damage.

Warnings of all these floods were issued promptly and in the main they were very accurate, especially those for the main stream. The total of losses and damage was small, aggregating, so far as was reported, only about $37,000, while the value of property saved estimated at $540,000, of which $500,000 was in the Cincinnati district.

There were no other floods of consequence east of the Rocky Mountains.

The Mississippi was frozen above St. Paul, Minn., at the end of the month, but was open below. Light running ice was reported as far south as Dubuque, Iowa, during the last week of the month. The Missouri River was generally frozen above Pierre, S. Dak., but was open at Pierre after December 14, and floating ice was observed as far south as Omaha, Nebr.

Severe and destructive floods occurred in the rivers of western Washington from December 12 to 16, inclusive, and the following report thereon was prepared by Mr. G. N. Salisbury, official in charge of the Weather Bureau Office at Seattle, Wash.

Floods in Washington—G. N. Salisbury, Meteorologist, Seattle.—This flooding of river valleys and lowlands was the combined effects of excessive rains and warm winds of the nature of Chinooks on both slopes of the Cascades, the floods not extending east of the Columbia River. The rains began on the 8th and 9th and the flood stage on the western slope began on the 12th or 13th, while on the eastern slope the flood stage was reached a day later. Practically all of the snow was melted to the summits on the western slopes and 18 to 24 inches from the eastern slope in three days.

At Snoqualmie Pass, the headwaters of the Snoqualmie River, the precipitation, mostly from rain, was 12.15 inches in five days, of which 11.75 inches occurred on the 10th, 11th, and 12th. Maximum temperatures of 55° to 60° were reached at most stations from the 10th to 12th. An average of 5.50 inches of precipitation occurred in three to four days in the flooded district, which was all of Washington from the coast to the one hundred and twentieth meridian, and from the Lewis River in latitude about 47° northward to the international boundary.

The principal rivers in flood east of the mountains were the Yakima, Wenatchee, and Stehekin, all heading in the Cascades. The high water was due entirely to Chinooks and excessive rains in the mountains near the summit, as there was no heavy precipitation in the lower reaches below Cle Elum on the Yakima or Leavenworth on the Wenatchee.

The Yakima is said to have reached the highest stage on record, although the consequent money loss was small. The reclamation project manager at Yakima estimates the entire damage to reservoirs and canals as $2,000, and the county engineer reports $1,000 as the loss to bridges and highways.

The damage in Kittitas County was slight. There were two deaths from drowning in the Yakima.

Some damage was occasioned by the high waters of the Wenatchee; four or five small cottages at Cashmere being washed away, but the money loss was not great.

The greatest damage occurred west of the Cascade Mountains, owing mainly to the nature of the country. The distance from the mountain summits to tidewater is so short that freshets come suddenly and there is scarcely a day in which to prepare; also the dikes near tidewater give way under the burden of the freshets, thus increasing the inundation. A great share of the damage and nearly all the loss of life was due to landslides caused by the excessive rain. The soil in western Washington being a glacial drift of clay and gravel loam overlying deposits of blue clay, the bluffs, banks, and cuts, although so solid as to be practically hardpan in dry weather, become softened by excessive rains. The blue-clay stratum attains the consistency of soft soap when saturated by excessive rains, and the banks slide down, often carrying houses and covering stretches of highway and railroad tracks. Experience has shown that the danger limit of saturation is in excessive rains of 2.50 inches in 24 hours. Six deaths occurred near Aberdeen from such a landslip in the recent storms, carrying a logging train down an embankment and burying the passengers. Four deaths were caused at Seattle by bluffs thus sliding, and several

were injured or endangered. Only two deaths occurred in western Washington from drowning in the flood. They were caused by a mail train from the east crashing through a broken bridge, at Miller River near Skykomish on the first day of the flood, December 12.

The inundation at Stanwood near Skagit Bay was principally due to the bursting of dikes; first on the Stillaguamish River, which was in flood, and a day or two later a dike which protected the little city from the overflow of the Skagit River let a wall of 8 feet of water loose, which caused a depth of 3 feet of water in the principal streets of Stanwood, a small town of about 1,000 inhabitants. Business was suspended for two or three days, and people went about the streets in boats. But there was no loss of life, and the property loss was small, amounting to about $5,000 from the suspension of business, so the postmaster reports. The cost of repairs to dikes is unknown. Florence and Silvana, small towns a few miles above Stanwood, suffered only slightly from loss of wages.

The greatest damage (by counties) occurred in Puyallup, White, Green, and Snoqualmie, in Snohomish, King, Pierce, Skagit, and Whatcom Counties, traversed by the Puyallup, White, Green, Snoqualmie, Stillaguamish, Snohomish, Skykomish, Skagit, and Nooksack Rivers. Grays Harbor, Pacific, Thurston, Lewis, Kitsap, Jefferson, and Clallam Counties suffered relatively small losses. The Snohomish County engineer estimates the damage to bridges and highways at $100,000; live stock and property, $10,000; crops, $10,000; suspension of business, $50,000. The King County engineer estimates the damage to roads and bridges at $125,000. The loss to Seattle from breaks in sewers, slides, etc., is not included in the engineer's estimate. The Whatcom County engineer estimates the loss to bridges at $7,000; this does not include all the loss in Whatcom County. The postmaster at Skykomish estimates the loss to bridges and highways in his vicinity at $20,000. The loss in the delta of the Skagit to stored crops, such as many tons of hay and thousands of sacks of oats, was several thousands of dollars. One farm alone lost $7,000. The loss of live stock in Whatcom, Skagit, and Snohomish Counties was considerable, but figures can not be given. The loss to highways and bridges in Kitsap County was placed at $100,000, but this is probably an overestimate and $50,000 would amply cover it. The loss in Jefferson and Clallam Counties, also Grays Harbor and Pacific Counties was considerable. Reports of the engineers of Skagit, Pierce, Mason, and Lewis Counties have not been received. The money loss from all sources in Pierce County is perhaps as great as in King County ($125,000), since there was much damage to bridges and highways, and the suspension of some mills.

The railroads suffered greatly from slides, washouts, and damage to bridges, which loss is not included in the foregoing.

The total loss in the flooded district is probably somewhat less than $1,000,000 all told.

In comparison with former floods this one is in dispute. The Skagit and Snohomish Rivers were probably higher than ever before in their history. It is difficult to compare the past flood with former stages of the rivers and especially with periods of more than 10 years ago, because since the introduction of automobiles, the nature of road building has changed so much. Also dikes have been constructed, channels narrowed, banks revetted, mouths dredged or on the contrary allowed to become filled up with silt, thus materially changing the condition of the rivers. The expense of constructing modern highways is so manyfold greater than that of the old dirt road that the cost of repairs or replacements forms no basis of comparison with former conditions. Besides there are no reliable gauges in the flooded areas to mark the stages, and therefore no reliable comparisons can be made.

Floods in southern California, H. B. Hersey, Meteorologist, Los Angeles.—A remarkably heavy rainfall occurring over southern California from the 17th to the 28th of December caused flood conditions in many localities. There had been practically no rain up to the 17th, when it began at a few points and on the 18th it became general and heavier. It continued raining nearly every day at most stations until the 28th, when it ended.

The precipitation was heaviest in the mountainous districts, but even on the desert there was considerable rain. One station, Opid's Camp, located about 5 miles northeast of Mount Wilson, recorded a total precipitation of 49.01 inches; three other stations reported between 30 and 40 inches and 13 others between 20 and 30 inches. Most of the precipitation was in the form of rain except at altitudes above 8,000 feet where a large portion of it was snow.

The ground was very dry and for the first three days absorbed a great portion of the rainfall except in the mountainous districts, so the damage was not so extensive as would be expected from such a heavy precipitation. Many roads were washed out and made impassable and several bridges were carried away and others damaged. Some cattle and other stock were drowned, but losses in this line were not important. No lives were lost, though many people had narrow escapes.

The highest reading of the river gauge at Los Angeles was made at noon of the 20th, when it read 12.5 feet. Mud marks on the gauge at that time showed that the water had been about a foot higher during the forenoon.

Mr. W. P. Hoge, special observer at Mount Wilson,[1] called this office by telephone about noon of the 20th and reported the excessive rainfall occurring since the morning observation. Warnings were immediately telephoned to the flood-control office, several railroad offices, and other affected by high water.

The check dams and reservoirs put in by the county flood-control board proved to be of great value and this work will undoubtedly be greatly extended.

[1] See page 660, this REVIEW.

Flood stages during December, 1921.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
GREAT LAKES DRAINAGE.					
Grand:	*Feet.*			*Feet.*	
Grand Rapids, Mich.	11.0	21	21	11.2	21
MISSISSIPPI DRAINAGE.					
Ohio.					
Marietta, Ohio	33.0	(*)	1	34.0	1
Point Pleasant, W. Va.	40.0	(*)	2	43.4	1
Do.	40.0	25	27	43.9	25
Dam No. 29, Ky.	50.0	1	1	50.5	1
Do.	50.0	26	27	52.5	26
Dam No. 30, Ky.	50.0	26	28	52.2	26
Portsmouth, Ohio.	50.0	26	28	53.5	27
Maysville, Ky.	50.0	26	28	52.3	27
Cincinnati, Ohio	50.0	25	30	56.1	27
Dam No. 35, Ky.	45.0	26	29	50.3	27
Madison, Ind.	46.0	26	29	47.9	28
Louisville, Ky.	28.0	26	30	32.3	28
Cloverport, Ky.	40.0	25	(†)	46.9	29
Henderson, Ky.	33.0	1	10	37.5	7
Do.	33.0	26	(†)	41.2	31
Evansville, Ind.	35.0	(*)	10	39.6	6
Do.	35.0	26	(†)	43.1	30
Mount Vernon, Ind.	35.0	2	10	38.8	7
Do.	35.0	27	(†)	42.5	31
Shawneetown, Ill.	35.0	1	11	39.6	8
Do.	35.0	27	(†)	43.2	31
Monongahela:					
Lock No. 15, W. Va.	22.0	24	25	27.2	24
Lock No. 10, W. Va.	25.0	24	24	27.0	24
Lock No. 7, Pa.	30.0	24	25	36.4	24
Lock No. 4, Pa.	31.0	25	25	38.8	25
Little Kanawha:					
Glenville, W. Va.	23.0	24	24	26.4	24
Creston, W. Va.	20.0	24	24	21.0	24
Walhonding:					
Walhonding, Ohio.	8.0	25	25	8.4	25
Hocking:					
Athens, Ohio.	17.0	24	26	20.9	25
Scioto:					
Circleville, Ohio.	10.0	25	26	12.0	25
Chillicothe, Ohio.	14.0	25	26	14.7	26
Licking:					
Farmers, Ky.	25.0	25	25	25.6	25
Falmouth, Ky.	28.0	24	26	40.8	24
South Fork of Licking:					
Cynthiana, Ky.	20.0	24	24	22.6	24
Green:					
Lock No. 4, Ky.	33.0	(*)	2	38.9	1
Lock No. 2, Ky.	34.0	1	8	37.0	5
Do.	34.0	28	(†)	35.8	30
Wabash:					
Vincennes, Ind.	14.0	1	3	16.0	1
Mount Carmel, Ill.	15.0	(*)	9	21.3	1
Do.	15.0	25	(†)	20.4	31
White:					
Decker, Ind.	18.0	(*)	2	19.5	1
Do.	18.0	5	7	18.5	6
Do.	18.0	26	(†)	22.7	31
East Fork of White:					
Shoals, Ind.	20.0	25	(†)	28.1	29
Williams, Ind.	10.0	26	(†)	17.3	28

* Continued from November, 1921. † Continued into January, 1922.

Flood stages during December, 1921—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
MISSISSIPPI DRAINAGE—continued.					
West Fork of White:	*Feet.*			*Feet.*	
Elliston, Ind.	19.0	3	3	19.1	3
Do.	19.0	25	28	22.8	27
Illinois:					
Peru, Ill.	14.0	(*)	(†)	16.6	19
Henry, Ill.	7.0	22	(†)	9.1	27, 29
Peoria, Ill.	16.0	1	(†)	17.6	24
Havanna, Ill.	14.0	4	15	14.4	7–10
Do.	14.0	21	29	14.4	25–26
Beardstown, Ill.	12.0	(*)	(†)	14.0	6–11
Willamette:					
Eugene, Oreg.	10.0	1	3	14.3	2
Albany, Oreg.	20.0	2	4	23.0	2
Salem, Oreg.	20.0	2	3	21.2	3
Oregon City, Oreg.	12.0	2	5	13.9	4
Portland, Oreg.	15.0	2	5	16.3	4
Santiam:					
Jefferson, Oreg.	10.0	(*)	2	13.0	1

* Continued from November, 1921. † Continued into January, 1922.

MEAN LAKE LEVELS DURING DECEMBER, 1921.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., Jan. 5, 1922.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level dur ng December, 1921:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.99	579.54	571.71	244.83
Above or below—				
Mean stage of November, 1921	−0.21	−0.10	−0.09	−0.02
Mean stage of December, 1920	−0.26	−0.56	−0.18	−0.57
Average state for December, last 10 years	−0.39	−0.62	−0.09	−0.68
Highest recorded December stage	−1.14	−3.04	−1.82	−2.78
Lowest recorded December stage	+0.79	+0.54	+0.85	+1.40
Average relation of the December level to:				
November level		−0.10	−0.10	−0.10
January level		+0.20	+0.20	+0.10

*Lake St. Clair's level: In December, 574.58 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, DECEMBER, 1921.

By J. WARREN SMITH, Meteorologist.

The month of December, 1921, was generally mild in all sections of the country, except in the Northeast and far Northwest, where the temperatures averaged below normal. It was mostly favorable for outdoor work, especially in Central and Southern States and much plowing was accomplished in the South. There was a serious lack of moisture in the central and southern Great Plains area and parts of the Southwest, but generous rains in California the latter part of the month were very beneficial in that State, while, at the same time needed rains occurred in the Southeast. Corn husking made generally good progress and at the close of the month corn was about all gathered in the principal producing States, although floods did some damage to the crop in fields in portions of the Ohio Valley.

There was a general absence of snow cover during most of the month in the principal winter wheat States, but there was not much damage reported from alternate freezing and thawing, as temperatures remained comparatively uniform. Fall-sown grains continued in satisfactory condition east of the Mississippi River, but the continued lack of moisture was harmful in the Great Plains area from Nebraska southward and wheat showed a steady deterioration in most of that section.

Hardy truck crops in the South suffered no material frost damage during the month, but tender vegetation was seriously injured in some southern localities the first half. Precipitation in the east Gulf States favorably affected truck in that area, but it continued too dry in the Southwest. Cane harvest made good progress in Louisiana, and the weather was favorable for stubble and fall planted cane in that State, while it was ideal for truck in the Imperial Valley of California.

The mild, open weather was favorable for stock in the Central and Eastern States, and considerable grazing was possible. It was also favorable for range and stock in the West except where drought prevailed in the Southwest. Considerable feeding was necessary in the far Northwest

on account of snow-covered range. Stock in general continued in satisfactory condition.

Heavy damage was done to citrus fruits in California by high winds the first part of the month, while frost did considerable harm to new foliage in that State. Navel oranges colored nicely, however, and a generally good crop of lemons was being gathered, while citrus ripened well in Florida. Strawberries did well also in the latter State and some were going to market during the last part of the month, when citrus fruits were moving in large quantities.

MONTHLY AND ANNUAL TEMPERATURE AND PRECIPITATION ANOMALIES, 1921.

Below are given the temperature and precipitation anomalies for the year 1921 by climatic districts published month by month in Table 1 of the REVIEW, thus reviving a practice that was abandoned in 1909.

The temperature table shows at a glance that the year just closed was especially warm over the greater portion of the United States and indeed was warmer than the normal in all parts of the country. The Pacific Coast States alone had the least excess; the Missouri Valley had the greatest.

Precipitation on the average of the year was almost universally deficient by small amounts, the Ohio Valley and Tennessee, the Upper Mississippi Valley, the north Pacific coast and the south Pacific coast only showing a small positive anomaly. The deficit was greatest in Florida, the East Gulf and South Atlantic States, New England, and California.

Monthly temperature departures, 1921 (degrees and tenths).

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
New England	+ 3.1	+ 2.8	+ 8.7	+5.3	+0.9	+0.7	+2.5	−0.6	+4.5	+1.8	−0.4	−1.6	+2.3
Middle Atlantic States	+ 3.3	+ 3.9	+10.6	+5.8	−0.7	+1.4	+2.7	−1.1	+5.7	+0.5	+2.4	+0.6	+2.9
South Atlantic States	+ 2.7	+ 2.6	+ 9.1	+2.1	−2.1	+1.6	−0.2	0.0	+6.3	−0.2	+4.5	+4.0	+2.5
Florida Peninsula	+ 1.8	+ 0.7	+ 3.9	+0.8	−2.1	−0.1	−0.9	0.0	+0.7	+0.4	+2.3	+3.4	+0.9
East Gulf States	+ 5.1	+ 2.4	+ 8.6	−0.8	−1.2	+2.5	+0.9	+1.7	+6.7	−0.5	+4.6	+4.8	+2.9
West Gulf States	+ 7.4	+ 3.7	+ 7.4	−1.9	+0.3	+0.2	+0.4	+2.2	+5.1	+0.9	+5.6	+4.8	+3.0
Ohio Valley and Tennessee	+ 5.4	+ 3.9	+10.5	+2.8	+0.6	+3.4	+3.4	−0.2	+5.7	−0.4	+3.3	+2.7	+3.4
Lower Lake Region	+ 4.9	+ 5.2	+10.1	+7.5	+2.1	+2.2	+5.9	−0.3	+5.0	+0.6	−0.3	+0.7	+3.6
Upper Lake Region	+ 7.3	+ 6.5	+ 7.0	+6.6	+3.4	+5.3	+7.6	+0.6	+5.3	+1.9	−1.4	+0.8	+4.2
North Dakota	+11.8	+12.9	+ 3.8	+1.1	+0.6	+5.6	+2.6	+1.2	+0.5	+5.2	−3.0	+5.0	+3.9
Upper Mississippi Valley	+ 9.5	+ 8.7	+ 9.0	+3.4	+2.6	+5.0	+4.5	+0.5	+4.3	+2.1	0.0	+3.1	+4.4
Missouri Valley	+11.6	+11.5	+ 9.2	+2.0	+1.3	+4.7	+2.7	+1.1	+3.8	+3.9	+0.4	+4.3	+4.7
Northern Slope	+ 7.0	+ 8.4	+ 4.8	−0.9	+0.2	+3.0	+1.4	+0.9	−2.4	+6.1	+0.8	−0.3	+2.4
Middle Slope	+ 7.8	+ 7.6	+ 6.9	−1.0	+1.7	+0.7	+0.8	+2.0	+4.2	+3.9	+3.0	+3.1	+3.4
Southern Slope	+ 6.2	+ 3.9	+ 5.4	−1.4	+0.2	−1.7	−0.8	+2.0	+5.4	+3.9	+4.8	+5.4	+2.8
Southern Plateau	+ 1.4	+ 2.4	+ 3.1	−2.3	−2.4	−0.5	−0.3	−0.3	+1.7	+3.0	+3.0	+3.9	+1.1
Middle Plateau	+ 4.1	+ 4.7	+ 3.8	−2.1	−0.5	+1.9	+1.1	−0.5	−0.7	+4.6	+3.7	+3.7	+2.0
Northern Plateau	+ 4.5	+ 2.6	+ 3.0	−3.1	0.0	+2.0	+0.7	+1.4	−5.0	+4.9	+2.8	−0.6	+1.1
North Pacific coast	+ 1.4	+ 2.6	+ 1.2	−0.9	−0.7	+1.6	−1.4	−0.4	−0.2	+2.4	+2.4	−2.2	+0.5
Middle Pacific coast	− 1.1	+ 1.0	+ 1.3	−0.6	−2.3	+1.8	+0.8	−0.7	+0.7	+1.7	+1.1	+1.4	+0.4
Southern Pacific coast	− 0.2	+ 1.8	+ 2.0	−0.8	−2.8	+0.6	+1.8	−0.3	+0.3	+2.6	+2.3	+3.4	+0.9

Precipitation departures, 1921 (inches and tenths.)

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
New England	−1.5	−0.6	−1.3	+0.5	−0.6	−0.4	+1.2	−1.7	−1.2	−1.6	+1.8	−1.2	−0.6
Middle Atlantic States	−1.1	−0.6	−1.2	0.0	+0.4	−1.5	−0.7	−1.0	−1.0	+1.6	+1.0	−1.1	−0.4
South Atlantic States	−0.8	−1.0	−2.5	−0.9	+0.7	−2.0	+2.4	−1.8	−1.9	−1.4	−0.4	−2.0	−1.0
Florida Peninsula	−1.5	−1.0	−0.1	−0.2	+1.2	−3.2	+0.2	−3.6	−4.6	+5.6	−0.6	−1.2	−0.8
East Gulf States	−2.3	−0.6	−0.8	+1.1	−1.1	−1.5	+0.2	−0.6	−1.4	−0.9	0.0	−1.3	−0.8
West Gulf States	−0.7	−0.7	+1.3	+0.9	−1.6	+1.7	−0.9	−1.0	+2.3	−2.1	−1.3	−1.2	−0.3
Ohio Valley and Tennessee	−1.1	−0.2	+1.0	+0.4	−1.2	−1.2	−0.9	+1.3	+1.2	−0.4	+2.7	+0.4	+0.2
Lower Lake	−1.6	−0.4	+1.1	+0.6	−1.2	−1.4	−0.6	0.0	+0.1	−0.2	+1.1	−1.4	−0.3
Upper Lake	−1.1	−0.7	+1.0	+1.5	−1.7	−1.4	−0.4	+1.4	+0.6	0.0	−0.1	+0.7	0.0
North Dakota	−0.4	−0.2	+0.2	+0.1	−0.4	−0.5	+0.1	+0.4	+1.6	−0.3	−0.2	−0.2	0.0
Upper Mississippi Valley	−0.8	−0.9	+0.8	+1.3	−1.0	−1.0	−1.5	+1.1	+2.9	−0.5	+0.5	+0.2	+0.1
Missouri Valley	−0.1	−0.5	+0.4	−0.4	−0.1	0.0	−0.5	−1.2	+2.0	−0.5	−0.7	−0.5	−0.2
Northern Slope	−0.1	−0.4	−0.2	−0.2	+0.3	−0.2	−0.6	−0.2	−0.3	−0.6	+0.4	+0.2	−0.2
Middle Slope	+0.2	−0.3	−0.6	+0.3	−2.4	+1.2	+0.3	+0.1	−0.1	−1.0	−0.7	−0.2	−0.3
Southern Slope	+0.1	+1.4	+0.2	−1.1	−1.2	+3.5	−0.7	−0.2	−2.0	−1.8	−1.1	−0.8	−0.3
Southern Plateau	−0.1	−0.5	−0.3	−0.2	+0.3	+0.4	+0.1	+0.6	+0.4	−0.2	−0.5	+0.4	0.0
Middle Plateau	−0.3	−0.7	−0.7	−0.3	+0.6	−0.2	+0.2	+0.6	−0.5	0.0	−0.4	+0.7	−0.1
Northern Plateau	0.0	−0.2	−0.4	0.0	−0.1	−0.6	−0.2	0.0	−0.1	−0.6	+1.2	−0.5	−0.1
North Pacific coast	+1.6	+1.7	−1.3	−0.4	−0.8	+0.3	−0.6	+0.5	+0.6	+1.7	+1.5	−1.8	+0.2
Middle Pacific coast	+1.3	−2.0	−3.8	−1.6	+0.1	−0.1	0.0	0.0	−0.4	−0.7	−0.7	+0.8	−0.6
Southern Pacific coast	+0.7	−1.4	−0.8	−0.8	+1.4	−0.1	0.0	0.0	+0.4	−0.5	−1.0	+4.8	+0.2

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December, 1921.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	51.5	+4.7	Selma	82	3†	3 stations	21	17†	3.43	−1.64	Tuscaloosa	5.72	Riverton	1.64
Arizona	46.8	+4.4	Tucson	89		Fort Valley	−7	24	1.50	+0.40	Prescott	5.29	2 stations	T.
Arkansas	47.1	+5.0	Mount Ida	82	13	2 stations	11	25	2.78	−1.31	Dumas	5.16	Magnolia	1.31
California	49.0	+2.3	Ojai	88	10	Madeline	−2	17	8.33	+4.30	Squirrel Inn	30.70	Greenland Ranch	0.10
Colorado	31.0	+6.5	Two Buttes	78	15	Crested Butte	−31	16	1.47	+0.51	Durango	7.37	Garnett	0.05
Florida	63.3	+4.1	Homestead	90	2	2 stations	28	5†	2.28	−0.64	Garniers	6.87	Ritta	0.00
Georgia	51.9	+4.8	Bainbridge	82	3	2 stations	20	30	2.08	−2.15	Clayton	5.60	Statesboro	0.35
Hawaii	70.0	+0.2	Mahukona	90	29	Waimea	47	28	12.99	+4.58	Eke	71.50	Olowalu	1.29
Idaho	27.7	+1.7	Lapwai	69	12	Stanley	−20	16	1.87	−0.26	Preston	6.52	Challis	0.50
Illinois	34.1	+3.9	Carbondale	66	6	Freeport	−6	25	2.89	+0.75	Shawneetown	4.64	Roberts	1.24
Indiana	35.2	+3.3	Vincennes	68	11	Goshen	−1	25	3.84	+1.13	Huntingburg	9.19	Kokomo	1.24
Iowa	28.2	+4.3	3 stations	69	13	Washta	−22	25	1.02	−0.20	Davenport	3.72	Harlan	T.
Kansas	34.5	+3.2	2 stations	81	13	Goodland	−7	24	0.47	−0.49	Pleasanton	1.51	8 stations	T.
Kentucky	41.7	+4.6	Berea	73	1	Berea	18	30	4.40	+0.46	Maysville	6.76	Bowling Green	1.37
Louisiana	57.6	+6.3	Houma	89	3	2 stations	20	18	4.67	−0.70	Merryville	7.60	Shreveport	1.92
Maryland-Delaware	36.2	+1.6	5 stations	70	1	Oakland, Md	2	22	2.51	−0.89	Oakland, Md	5.30	Chesapeake City, Md.	1.72
Michigan	26.5	+1.5	South Haven	63	1	Humboldt	−30	22	2.80	+0.67	Deer Park	8.18	St. Ignace	0.83
Minnesota	17.1	+2.4	Lynd	63	4	Pokegama Falls	−41	24	0.55	−0.30	Norden	2.42	2 stations	T.
Mississippi	52.7	+5.8	Fayette	84	14	Okolona	17	18	3.95	−1.47	Merrill	7.44	Aberdeen	1.54
Missouri	36.9	+3.8	Dean	74	13	Bethany No. 2	−8	25	1.86	−0.23	Marble Hill	3.74	Liberty	0.13
Montana	21.2	−1.4	Sun River Canyon	67	12	Wheaton	−35	20	1.06	+0.17	Heron	4.31	Bennett Farms	0.00
Nebraska	29.8	+3.9	2 stations	76	13	Nenzel	−23	24	0.35	−0.38	Kimball	1.20	2 stations	0.00
Nevada	35.2	+3.6	Las Vegas	75	11	Rye Patch	−11	16	1.80	+0.88	Sharps	4.35	Mina	0.40
New England	23.7	−2.0	Voluntown, Conn	62	3	2 stations	−27	30	2.23	−1.14	Colchester, Conn	3.60	Ashland, Me	0.76
New Jersey	32.2	−0.5	Vineland	64	1	Culvers Lake	−9	22	2.37	−1.62	Dover	3.23	Bergen Point	1.62
New Mexico	40.1	+6.3	Pearl	82	12†	Red River Canyon	−12	4	0.39	−0.33	Schuster Springs R. S.	3.33	15 stations	0.00
New York	25.7	−0.5	Dansville	64	2	Wanakena	−29	30	1.73	−1.28	Bedford Hills	3.76	Avon	0.15
North Carolina	45.1	+3.7	Weldon	76	1	Willard	15	31	2.45	−1.41	Rock House	6.83	Elizabethtown	0.87
North Dakota	16.4	+3.4	Edgeley	59	14	Pettibone	−33	24	0.40	−0.14	Amenia	1.60	4 stations	T.
Ohio	33.7	+2.8	Lancaster	70	17	2 stations	2	22	3.34	+0.29	Portsmouth	6.56	North Bass Island	0.90
Oklahoma	43.8	+4.5	Oakwood	89	14	2 stations	0	25	0.73	−0.88	Wilberton	3.04	2 stations	0.00
Oregon	33.7	−1.3	Clarno	74	12	Madras	−19	21	2.26	−2.03	Government Camp	8.74	Ochoco	0.21
Pennsylvania	31.6	+0.8	Gettysburg	66	1	West Bingham	−11	30	2.59	−0.61	Girardville	6.25	Holtwood	0.91
South Carolina	50.3	+4.0	Paris Island	80	4	Kingstree	20	31	1.54	−1.82	Walhalla	3.37	Yemassee	0.31
South Dakota	23.7	+2.8	2 stations	72	12†	Pollock	−34	24	0.52	−0.16	Spearfish	2.38	Onida	0.04
Tennessee	44.7	+4.8	4 stations	73	23†	Pinewood	15	18	2.67	−1.88	Rugby	4.38	Newport	1.34
Texas	55.0	+5.5	Encinal	98	1†	Dalhart	6	17	1.49	−0.67	Bon Wier	7.60	21 stations	0.00
Utah	33.2	+7.0	Springdale	74	13†	East Portal	−10	8	2.62	+1.27	Silver Lake	12.34	Manila	0.34
Virginia	40.0	+2.6	3 stations	72	1†	Mount Weather	4	22	2.59	−0.73	Diamond Springs	5.05	Lynchburg	1.01
Washington	31.5	−1.9	Walla Walla	73	12	Snyders Ranch	−12	19	4.18	−0.50	Paradise Inn	16.15	Attalia	0.31
West Virginia	37.0	+3.8	Hinton	79	1	Cheat Bridge	0	30	4.25	+0.94	Pickens	7.51	Harpers Ferry	1.11
Wisconsin	21.3	+0.6	Hancock	57	1	Winter	−35	25	2.05	+0.75	Sturgeon Bay	4.15	Grantsburg	0.45
Wyoming	23.7	+2.7	Sheridan	66	12	2 stations	−24	23†	1.24	+0.51	Bedford	3.72	Powell	0.11

* For description of tables and charts, see REVIEW, January, 1921, page 41.

† Other dates also.

TABLE 1.—*Climatological data for Weather Bureau Stations, December, 1921.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*		%	*In.*	*In.*		*Miles*							*0–10*	*In.*	*In.*
New England.							**27.5**	**— 1.6**											**72**	**2.17**	**— 1.2**									**6.3**		
Eastport	76	67	85	29.80	29.89	— .09	24.6	— 0.7	51	18	32	— 4	22	17	37	23	18	75	1.33	— 2.6	11	10,043	nw.	45	s.	18	7	12	12	5.9	6.6	1.8
Greenville, Me	1,070	6																														
Portland, Me	103	82	117	29.84	29.97	— .06	25.6	— 1.5	51	18	33	— 2	30	18	31	23	16	69	3.35	— 0.3	12	6,492	nw.	47	s.	18	9	10	12	5.7	9.4	5.1
Concord	288	70	79	29.64	29.97	— .09	23.2	— 3.2	51	18	32	— 6	22	15	31				2.64	— 0.7	11	4,037	nw.	28	w.	18	10	5	16	5.9	9.6	7.0
Burlington	404	11	48	29.51	29.98	— .07	20.3	— 2.2	37	18	28	—12	30	12	35				0.81	— 0.9	15	10,711	s.	48	s.	18	4	4	23	7.9	7.8	1.2
Northfield	876	12	60	29.00	29.99	— .06	17.4	— 3.1	51	18	28	—19	26	7	40	16	12	80	1.40	— 1.3	14	6,038	n.	40	sw.	18	5	9	17	7.1	5.9	5.9
Boston	125	115	188	29.83	29.97	— .08	31.4	— 0.2	59	18	39	2	22	24	33	28	21	64	2.35	— 1.1	11	8,750	w.	39	s.	18	9	9	13	6.1	4.4	0.3
Nantucket	12	14	90	29.94	29.95	— .10	34.2	— 2.5	54	3	40	8	22	28	31	32	28	78	2.45	— 1.2	14	12,148	w.	46	w.	21	4	4	23	7.9	3.9	0.0
Block Island	26	11	46	29.95	29.98	— .08	34.0	— 2.6	60	2	40	7	30	27	33	31	27	75	2.16	— 1.7	10	16,354	nw.	72	nw.	21	7	8	16	6.6	3.8	0.0
Providence	160	215	251	29.80	29.98	— .06	30.9	— 0.7	59	2	38	3	22	24	31	27	21	68	2.43	— 1.4		10,954	nw.	58	nw.	21	12	6	13	5.5	2.4	0.0
Hartford	159	122	140	29.83	30.01	— .06	30.0	+ 0.2	57	18	38	1	22	22	31	26	20	71	2.36	— 1.2	9	6,028	nw.	44	s.	18	10	7	14	5.9	1.4	T.
New Haven	106	74	153	29.90	30.02	— .05	30.6	— 1.2	57	2	38	2	22	23	33	27	22	72	2.64	— 1.0	9	7,301	n.	37	s.	18	11	12	8	5.0	2.5	0.0
Middle Atlantic States.							**33.8**	**+ 0.6**											**73**	**2.07**	**— 1.1**									**6.0**		
Albany	97	102	115	29.91	30.02	— .06	26.6	— 0.9	60	18	35	— 2	30	18	34	24	20	76	1.19	— 1.4	7	6,268	nw.	43	s.	18	12	5	14	5.6	2.8	1.0
Binghamton	871	10	84	29.04	30.00	— .09	27.4	— 0.3	57	18	35	— 1	22	20	32				1.75	— 0.7	10	5,199	nw.	40	w.	18	5	6	20	7.5	5.4	2.0
New York	314	414	454	29.68	30.03	— .06	33.8	— 0.6	58	1	42	4	30	26	32	29	23	60	1.89	— 1.6	9	14,446	nw.	70	nw.	21	11	5	15	5.5	7.3	0.0
Harrisburg	374	94	104	29.66	30.08	— .04	33.6	+ 0.8	59	18	40	9	22	27	32	30	23	68	2.60	0.0	9	5,356	nw.	59	sw.	18	8	8	15	6.1	5.0	T.
Philadelphia	117	123	190	29.93	30.06	— .05	35.6	— 0.1	60	1	42	12	22	29	34	32	26	69	2.10	— 0.9	8	6,855	nw.	31	nw.	21	10	7	14	6.0	5.9	0.0
Reading	325	81	98	29.70	30.06		33.4		60	18	40	9	22	26	31	30	27	79	2.17	— 1.2	9	5,368	nw.	43	sw.	18	7	10	14	6.3	4.1	0.0
Scranton	805	111	119	29.14	30.04	— .06	29.6	— 0.2	58	18	37	3	22	22	31	27	23	80	1.83	— 0.8	11	6,176	sw.	44	sw.	18	3	12	16	7.0	3.7	0.2
Atlantic City	52	37	48	29.99	30.05	— .05	35.9	— 0.5	57	1	43	11	22	29	33	33	29	77	2.30	— 1.4	8	8,732	nw.	60	s.	18	14	3	14	5.0	3.4	0.0
Cape May	18	13	49	30.07	30.09	— .02	36.8	— 1.2	59	1	43	12	22	31	30	34	30	78	2.50	— 1.3	13	7,146	nw.	40	s.	31	11	8	12	5.8	4.2	0.0
Sandy Hook	22	10	55																													
Trenton	190	159	183	29.83	30.04		33.0		61	2	41	9	22	25	34	30	26	78	1.85	— 1.3	9	7,940	w.	48	w.	18	9	8	14	5.9	7.8	0.0
Baltimore	123	100	113	29.93	30.07	— .06	37.2	+ 0.3	60	1	44	12	22	30	34	33	27	68	2.08	— 1.0	11	4,069	sw.	24	s.	18	11	7	13	5.8	8.6	0.0
Washington	112	62	85	29.94	30.07	— .06	37.9	+ 2.8	66	1	45	12	22	31	33	33	26	67	1.95	— 1.2	12	5,110	nw.	35	nw.	29	11	4	16	6.1	5.5	0.0
Lynchburg	681	153	188	29.31	30.07	— .07	42.3	+ 4.0	71	1	52	18	22	33	29	36	31	70	1.01	— 2.3	9	5,783	w.	46	n.	29	10	11	10	5.3	0.0	0.0
Norfolk	91	170	205	29.99	30.09	— .04	44.2	+ 1.2	69	24	52	22	30	36	31	38	34	72	3.69	+ 0.2	9	9,886	ne.	41	n.	21	10	7	14	5.8	T.	0.0
Richmond	144	11	52	29.93	30.09	— .05	41.0	0.0	67	24	50	17	22	32	31	36	31	73	3.02	0.0	11	6,154	ne.	34	s.	18	6	12	13	6.3	T.	0.0
Wytheville	2,304	49	56	27.64	30.08	— .07	38.6	+ 3.3	64	1	46	21	10	31	30	34	30	74	1.25	— 2.5	8	6,856	w.	42	w.	17	8	7	16	6.6	T.	0.0
South Atlantic States.							**51.1**	**+ 4.0**											**74**	**1.52**	**— 2.0**									**4.9**		
Asheville	2,255	70	84	27.70	30.12	— .04	43.2	+ 5.4	67	1	52	23	30	34	33	37	32	70	1.38	— 2.7	6	7,963	nw.	44	se.	2	12	6	13	5.4	0.0	0.0
Charlotte	779	55	62	29.24	30.09	— .07	47.1	+ 4.2	69	1	56	28	30	38	26	41	36	71	2.66	— 1.2	5	4,285	sw.	27	w.	14	12	7	12	5.0	0.0	0.0
Hatteras	11	12	50	30.06	30.07	— .06	50.1	+ 1.3	71	4	57	31	30	44	28	46	43	81	1.95	— 3.2	8	12,390	n.	52	sw.	18	9	11	11	5.5	0.0	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.68	30.10	— .05	45.8	+ 3.1	71	1	55	25	30	37	29	39	35	73	2.86	— 0.3	6	5,995	sw.	34	nw.	5	6	16	9	5.6	0.0	0.0
Wilmington	78	81	91	30.02	30.11	— .04	50.4	+ 3.2	73	25	60	28	30	41	34	44	40	74	1.54	— 1.6	8	5,373	w.	32	sw.	18	13	11	7	4.6	0.0	0.0
Charleston	48	11	92	30.06	30.11	— .04	55.0	+ 3.7	76	24	64	36	30	46	28	48	44	75	0.51	— 2.6	6	7,982	w.	35	ne.	22	14	11	6	4.1	0.0	0.0
Columbia, S. C	351	41	57	29.73	30.12	— .04	51.2	+ 4.0	73	3	62	30	30	40	31	44	38	70	1.21	— 1.7	6	5,082	w.	34	w.	2	13	8	10	4.9	0.0	0.0
Due West	711	10	55	29.34	30.13		48.6		69	14	58	26	30	39	28				1.46		6	6,719	sw.	40	w.	14	11	9	11	4.9	0.0	0.0
Greenville	1,039	113	122	28.96	30.08		48.0		67	3	58	28	30	38	26	41	35	68	2.80		6	6,449	sw.	42	w.	14	13	8	10	4.6	0.0	0.0
Augusta	180	62	77	29.91	30.11	— .05	52.6	+ 5.6	74	3	63	29	31	42	33	46	41	74	0.93	— 2.5	5	4,069	nw.	24	nw.	4	11	13	7	4.9	0.0	0.0
Savannah	65	150	194	30.04	30.11	— .04	56.2	+ 4.9	76	14	66	36	30	47	29	49	46	77	0.61	— 2.5	7	9,171	w.	45	nw.	4	14	3	14	4.9	0.0	0.0
Jacksonville	43	209	245	30.07	30.12	— .02	59.7	+ 4.5	76	25	68	38	5	51	26	54	51	80	1.60	— 1.4	5	8,970	n.	37	e.	16	15	9	7	4.5	0.0	0.0
Florida Peninsula.							**69.8**	**+ 3.4**											**77**	**0.85**	**— 1.2**									**3.4**		
Key West	22	10	64	30.06	30.08	.00	73.4	+ 3.3	83	3	78	63	6	69	14	67	65	80	0.35	— 1.5	3	7,638	ne.	35	nw.	10	20	11	0	2.5	0.0	0.0
Miami	25	71	79	30.08	30.11		69.6	+ 1.6	83	9	77	46	6	62	25	64	60	75	0.23	— 2.0	2	6,098	e.	29	w.	10	14	13	4	3.8	0.0	0.0
Sand Key	23	39	72	30.06	30.09	+ .01	73.0		80	3	75	64	6	71	8	67	64	74	0.17		4	9,920	ne.	44	nw.	10	20	11	0	2.5	0.0	0.0
Tampa	35	79	92	30.07	30.11	— .01	66.5	+ 5.3	80	26	75	48	30	58	23	59	56	80	1.98	0.0	6	4,590	ne.	25	e.	16	10	16	5	4.6	0.0	0.0
East Gulf States.							**54.0**	**+ 4.8**											**76**	**3.26**	**— 1.3**									**5.1**		
Atlanta	1,174	190	216	28.86	30.12	— .04	48.3	+ 3.7	68	3	57	29	18	40	24	44	40	76	1.79	— 2.8	9	9,803	w.	42	w.	17	11	4	16	5.6	0.0	0.0
Leesburg	279	10	55																													
Macon	370	78	87	29.72	30.13	— .03	52.0	+ 5.2	74	14	63	30	19	41	33	45	41	73	1.13	— 3.3	6	4,401	nw.	33	se.	2	13	8	10	4.7	0.0	0.0
Thomasville	273	49	58	29.82	30.12	— .03	57.8	+ 5.3	78	3	68	36	31	48	33	50	45	72	2.14	— 1.6	8	3,170	ne.	18	sw.	2	14	8	9	4.9	0.0	0.0
Pensacola	56	149	185	30.07	30.13	— .02	58.3	+ 4.4	77	14	66	35	5	50	29	54	52	83	4.51	+ 0.3	9	9,692	n.	50	sw.	17	16	5	10	4.5	0.0	0.0
Anniston	741	9	57	29.34	30.15	— .01	48.2	+ 4.0	73	3	60	25	30	37	34				3.70	— 0.8	10	4,512	nw.	25	s.	17	13	5	13	5.4	0.0	0.0
Birmingham	700	11	48	29.38	30.16	.00	50.2	+ 2.9	74	3	60	27	18	40	33	44	39	71	3.23	— 1.4	9	5,581	n.	30	se.	17	8	12	11	5.4	0.0	0.0
Mobile	57	125	161	30.06	30.12	— .03	57.4	+ 5.9	76	3	67	35	26	48	31	53	50	83	5.54	+ 1.0	7	7,187	n.	32	nw.	14	11	10	10	4.9	0.3	0.0
Montgomery	223	100	112	29.89	30.15	— .01	53.2	+ 4.1	77	3	63	31	26	43	29	47	43	74	2.71	— 1.8	10	4,607	w.	23	se.	1	15	5	11	4.8	0.0	0.0
Corinth	469	6					47.6		73	23	58	22	18	37	37				2.23		11		s.			7	15	9		0.0	0.0
Meridian	375	85	93	29.73	30.13	— .03	52.8	+ 5.9	78	3	64	29	26	42	36	47	43	75	3.29	— 1.9	9	4,189	ne.	24	se.	1	11	8	12	5.3	0.0	0.0
Vicksburg	247	65	73	29.86	30.15	.00	54.7	+ 5.3	79	3	64	29	26	46	34	48	44	75	4.29	— 0.7	9	5,340	se.	28	sw.	24	10	7	14	5.9	0.0	0.0
New Orleans	53	76	84	30.07	30.13	.00	60.8	+ 6.4	83	3	69	39	18	52	30	55	52	80	3.49	— 1.0	7	4,809	se.	22	n.	24	13	6	12	4.9	0.0	0.0
West Gulf States.							**53.9**	**+ 4.8**											**75**	**1.68**	**— 1.2**									**5.5**		
Shreveport	249	77	93	29.86	30.13	.00	54.6	+ 5.7	78	13	65	27	18	44	34	48	44	75	1.92	— 2.4	7	5,453	nw.	28	w.	17	12	7	12	5.5	0.0	0.0
Bentonville	1,303	11	44				41.6	+ 4.1	72	13	52	14	25	32	39				1.86		7						10	6	15		0.4	0.0
Fort Smith	457	79	94	29.63	30.12	— .01	45.2	+ 3.5	72	13	54	19	25	36	35	40	36	73	2.23	— 0.6	4	6,843	e.	39	sw.	23	8	8	15	6.4	T.	0.0
Little Rock	357	136	144	29.73	30.12	— .02	48.0	+ 4.5	75	13	57	21	25	39	32	42	37	71	2.58	— 1.7	7	6,843	s.	39	nw.	17	9	8	14	6.2	0.0	0.0
Brownsville	57	4	26				67.7		89	13	80	39	10	56	33				0.17		1		se.								0.0	0.0
Corpus Christi	20	69	77	30.09	30.11	— .01	62.7	+ 6.1	85	2	72	35	25	54	33	57	53	80	1.26	— 0.1	3	7,910	s.	39	s.	23	16	10	5	4.3	0.0	0.0
Dallas	512	109	117	29.58	30.14		51.0		80	28	62	19	25	40	34				0.67		4	6,424	nw.	39	nw.	3	9	14	8	5.0	0.0	0.0
Fort Worth	670	106	114	29.38	30.11	— .01	51.2	+ 3.7	81	28	64	17	25	39	35	43	36	61	0.34	— 0.9	4	7,262	nw.	38	nw.	3	13	13	5	4.1	T.	0.0
Galveston	54	106	114	30.08	30.14	— .02	60.2	+ 3.9	77	3	67	38	25	53	30	57	55	86	2.76	— 1.0	8	8,686	se.	42	nw.	17	8	15	8	5.4	0.0	0.0
Groesbeck	461	11	56																													
Houston	138	111	121	29.96	30.11		60.3	+ 5.8	82	13	70	31	25	50	32				3.50		9	6,200	se.	31	nw.	4	9	8	14	6.0	0.0	0.0
Palestine	510	64	72	29.58	30.12	.00	54.4	+ 5.0	80	14	65	24	25	44	33	47	41	68	2.92	— 0.8	6	5,706	s.	27	nw.	17	10	5	16	5.7	0.0	0.0
Port Arthur	34	58	66	30.07	30.11		58.8		78	3	67	35	5	50	32	55	53	89	2.53		8	6,754	s.	37	sw.	1	9	6	16	6.0	0.0	0.0
San Antonio	701	119	132		30.12	+ .01	59.0	+ 5.9	83	13	70	30	25	47	36				0.23	— 1.3	3	5,859	sw.	32	nw.	3	14	11	6		0.0	0.0
Taylor	582	55	63	29.53	30.15	+ .04	55.4	+ 4.8	81	2	68	24	25	43	39				0.91	— 1.7	5	6,486	n.	31	n.	17	10	7	14	5.4	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau Stations, December, 1921*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
Ohio Valley and Tennessee.							**39.3**	**+ 2.7**											**76**	**3.78**	**+ 0.4**									**7.3**		
Chattanooga	762	189	213	29.32	30.14	— .02	46.8	+ 4.2	65	24	55	29	18	38	27		41	35	68	2.86	— 1.5	9	6,609	nw.	34	w.	17	9	9	13	5.8	T.	0.0
Knoxville	996	102	111	29.04	30.12	— .04	44.4	+ 4.7	64	24	52	27	30	37	29		40	35	74	2.26	— 1.9	9	5,196	sw.	36	sw.	17	10	5	16	6.2	T.	0.0
Memphis	399	76	97	29.73	30.16	+ .01	48.1	+ 4.6	73	23	56	27	25	40	33		43	38	72	2.53	— 1.8	10	6,839	n.	40	sw.	24	8	6	17	6.6	0.0	0.0
Nashville	546	168	191	29.54	30.13	— .02	48.8	+ 3.7	67	23	53	26	10	36	36		40	35	71	1.76	— 2.1	8	8,374	nw.	41	w.	17	10	6	15	6.2	0.0	0.0
Lexington	989	193	230	29.00	30.10	— .04	38.9	+ 2.5	64	1	46	22	22	32	30		....	....	....	5.74	+ 2.4	9	11,399	sw.	50	w.	17	6	3	22	7.7	0.2	0.0
Louisville	525	219	255	29.52	30.11	— .03	40.6	+ 2.7	65	1	48	25	18	33	32		35	31	72	5.49	+ 1.8	8	10,332	s.	48	w.	17	6	7	18	7.2	T.	0.0
Evansville	431	139	175	29.63	30.11	— .02	41.0	+ 4.6	63	1	48	26	25	34	28		36	32	73	5.18	+ 1.4	8	9,590	sw.	46	w.	17	4	14	13	6.8	0.2	0.0
Indianapolis	822	194	230	29.15	30.06	— .06	35.2	+ 2.6	58	1	42	21	25	29	32		32	29	77	3.27	+ 0.2	11	10,300	sw.	46	w.	31	3	9	19	8.0	4.3	T.
Royal Center	736	11	55	....	....	....	....	....	....	....	....	....	....	....	....		....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Terre Haute	575	96	129	29.44	30.07	.....	36.8	.....	59	1	43	20	25	30	30		33	30	79	3.43	.....	9	8,429	nw.	40	s.	16	6	9	16	6.9	3.7	0.0
Cincinnati	628	11	51	29.39	30.09	— .04	36.4	+ 2.0	62	1	43	20	22	30	31		....	31	79	4.86	+ 1.9	12	7,079	sw.	41	sw.	17	3	8	20	7.9	2.8	0.0
Columbus	824	179	222	29.16	30.06	— .06	33.8	+ 1.0	61	1	40	13	22	28	29		32	28	80	3.74	+ 1.0	12	9,157	nw.	56	nw.	31	2	6	23	8.5	4.1	T.
Dayton	899	181	216	29.06	30.04	.....	34.8	+ 1.7	62	1	41	17	22	29	31		32	28	79	3.48	+ 0.9	11	9,245	sw.	50	sw.	17	5	8	18	7.5	4.3	0.0
Elkins	1,947	59	67	27.96	30.09	— .03	34.6	+ 2.1	65	1	43	12	22	26	30		32	29	82	5.07	+ 1.6	17	5,042	w.	39	w.	17	1	14	16	7.8	15.5	0.0
Parkersburg	638	77	84	29.42	30.09	— .05	37.4	+ 2.2	66	17	44	15	22	31	29		34	30	76	4.30	+ 1.5	12	4,937	se.	35	nw.	2	3	10	18	7.4	5.8	0.0
Pittsburgh	842	353	410	29.13	30.06	— .05	34.0	— 0.7	63	17	40	9	22	28	28		31	27	77	2.36	— 0.4	10	8,969	sw.	56	w.	17	0	5	26	8.8	7.2	T.
Lower Lake Region.							**29.8**	**+ 0.7**											**77**	**1.34**	**— 1.4**									**8.1**		
Buffalo	767	247	280	29.14	29.99	— .07	29.9	— 0.2	57	2	36	6	21	23	28		27	24	79	0.86	— 2.5	15	15,181	w.	96	sw.	18	1	5	25	9.0	3.9	0.4
Canton	448	10	61	29.46	29.96	.....	21.8	— 0.9	57	18	31	—15	30	13	36		....	....	....	1.60	— 2.0	13	8,869	sw.	70	sw.	18	6	9	16	6.6	6.3	2.6
Oswego	335	76	91	.....	30.00	— .06	27.2	— 2.0	58	18	34	— 4	22	20	31		....	....	....	0.43	— 2.2	16	10,490	s.	50	sw.	18	1	9	21	....	7.7	2.5
Rochester	523	86	102	29.42	30.01	— .05	29.2	+ 0.3	57	18	36	5	26	23	28		26	21	71	1.25	— 1.6	15	7,550	w.	53	sw.	18	1	6	24	8.8	6.9	2.0
Syracuse	597	97	113	29.34	30.00	— .07	27.1	— 1.2	58	18	34	— 5	22	20	35		....	....	....	0.95	— 1.7	13	9,872	s.	72	sw.	18	2	6	23	8.0	6.8	3.3
Erie	714	130	166	29.21	30.00	— .07	32.4	+ 0.7	60	1	38	13	21	27	25		29	25	72	1.33	— 1.7	12	11,676	nw.	59	sw.	18	1	8	22	8.3	2.9	T.
Cleveland	762	190	201	29.19	30.04	— .05	32.6	+ 1.5	58	17	38	11	22	27	22		30	26	77	1.75	— 0.8	15	11,048	s.	52	w.	31	1	5	25	8.7	7.9	T.
Sandusky	629	62	103	29.32	30.03	— .06	32.8	+ 1.7	60	1	38	14	22	28	20		....	....	....	1.55	— 0.8	14	10,535	sw.	52	w.	18	3	6	22	8.3	4.2	T.
Toledo	628	208	243	29.34	30.04	— .04	32.0	+ 1.5	57	1	38	11	25	26	26		30	26	77	1.66	— 0.6	11	11,330	sw.	64	sw.	17	3	10	18	7.5	5.2	T.
Fort Wayne	856	113	124	29.10	30.05	.....	32.4	+ 5.1	60	1	38	12	25	26	30		30	27	82	1.65	.....	13	7,887	sw.	42	sw.	31	4	5	22	8.0	4.9	T.
Detroit	730	218	245	29.21	30.02	— .05	30.6	+ 1.1	55	2	36	11	22	25	24		29	25	79	2.04	— 0.4	12	8,978	nw.	54	sw.	18	3	7	21	7.9	10.1	T.
Upper Lake Region.							**25.3**	**+ 0.8**											**82**	**2.84**	**+ 0.7**									**8.1**		
Alpena	609	13	92	29.28	29.97	— .05	25.4	+ 0.6	50	1	31	— 4	25	29	24		24	21	83	3.16	+ 0.9	16	9,139	nw.	44	nw.	29	2	7	22	8.3	13.8	4.8
Escanaba	612	54	60	29.30	30.00	— .03	22.6	+ 1.0	43	1	29	— 5	25	17	30		21	18	83	2.54	+ 0.8	13	7,267	nw.	36	n.	17	6	6	19	7.1	11.2	5.0
Grand Haven	632	54	89	29.30	30.01	— .04	30.6	+ 0.5	54	1	36	6	24	25	21		28	25	79	3.56	+ 1.0	16	10,589	n.	64	w.	31	0	5	26	9.0	9.3	T.
Grand Rapids	707	70	87	29.23	30.03	— .02	30.2	+ 1.4	54	1	36	8	25	25	20		28	25	79	4.14	+ 1.6	12	4,986	w.	38	w.	31	0	6	25	9.0	10.7	T.
Houghton	684	62	99	29.23	29.98	— .04	21.8	+ 0.9	41	1	27	— 6	25	16	24		....	....	....	0.80	— 0.6	15	8,080	nw.	43	nw.	28	0	2	29	9.3	17.4	12.0
Lansing	878	11	62	29.03	30.00	.....	28.4	+ 1.6	54	2	35	3	25	22	23		27	24	86	3.54	+ 1.5	15	5,622	nw.	28	nw.	31	0	10	21	8.4	8.3	T.
Ludington	637	60	66	29.28	30.00	.....	29.0	.....	54	1	34	2	22	24	22		27	24	81	3.55	.....	16	9,579	nw.	45	sw.	31	1	7	23	8.5	11.8	1.5
Marquette	734	77	111	29.18	30.01	— .01	22.9	— 0.0	42	1	28	— 3	21	17	22		20	18	82	2.04	— 0.5	22	8,454	w.	39	s.	28	1	5	25	8.7	19.8	15.3
Port Huron	638	70	120	29.28	30.00	— .06	29.0	+ 1.7	54	2	35	7	25	23	22		27	24	83	1.60	— 0.6	11	9,943	nw.	54	w.	31	1	12	18	7.9	6.5	T.
Saginaw	641	69	77	29.29	30.00	.....	28.2	.....	54	2	34	4	25	22	22		27	24	86	2.32	+ 0.4	13	7,035	nw.	33	sw.	31	1	9	21	8.2	4.3	T.
Sault Sainte Marie	614	11	52	29.25	29.98	— .02	20.8	+ 0.3	44	2	27	—10	24	14	22		20	18	87	3.43	+ 1.0	18	7,173	se.	39	nw.	2	1	8	22	8.4	18.1	10.5
Chicago	823	140	310	29.14	30.05	— .03	32.5	+ 3.2	57	1	39	8	25	26	32		30	26	76	4.63	+ 2.6	12	9,971	nw.	50	sw.	31	3	10	18	7.4	4.2	T.
Green Bay	617	109	144	29.32	30.01	— .03	21.8	+ 0.5	50	1	28	—10	25	15	29		20	18	82	3.65	+ 1.8	11	8,477	sw.	50	nw.	31	6	3	22	7.9	12.4	5.0
Milwaukee	681	125	139	29.26	30.03	— .03	27.8	+ 1.8	53	1	34	0	21	21	26		26	22	77	2.54	+ 0.6	12	8,072	nw.	36	nw.	31	4	8	19	7.4	6.5	T.
Duluth	1,133	11	47	28.77	30.05	.00	14.8	— 2.9	41	10	23	—22	24	7	31		13	12	91	0.69	— 0.5	8	10,042	nw.	56	nw.	31	11	5	15	5.8	7.8	5.2
North Dakota.							**16.9**	**+ 5.0**											**84**	**0.43**	**— 0.2**									**5.6**		
Moorhead	940	50	58	29.07	30.13	+ .05	16.5	+ 5.8	47	13	25	—23	24	8	33		15	12	85	0.35	— 0.4	9	6,572	nw.	36	nw.	13	4	10	17	6.8	2.9	2.3
Bismarck	1,674	8	57	28.30	30.19	+ .11	18.6	+ 3.6	51	13	27	—24	25	10	33		16	13	82	0.29	— 0.3	5	6,557	nw.	41	nw.	13	5	5	11	4.8	3.9	3.5
Devils Lake	1,482	11	44	28.44	30.10	+ .04	15.2	+ 7.2	41	13	23	—24	20	7	36		13	11	87	0.75	+ 0.4	10	7,843	nw.	36	nw.	13	14	4	13	5.2	7.8	5.8
Ellendale	1,457	10	56	....	....	....	....	....	....	....	....	....	....	....	....		....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Grand Forks	835	12	89	....	....	....	12.7	.....	42	5	23	—25	23	3	41		12	....	....	0.47	.....	10	.....	nw.	40	nw.	31	10	12	9	....	3.5	3.7
Williston	1,878	41	48	28.07	30.15	+ .09	17.2	+ 3.6	46	13	25	—24	20	10	33		15	13	84	0.33	— 0.3	6	6,224	w.	33	nw.	30	11	7	13	5.5	4.5	3.6
Upper Mississippi Valley.							**30.4**	**+ 3.1**											**80**	**1.96**	**+ 0.2**									**6.6**		
Minneapolis	918	102	208	29.04	30.02	.....	20.4	.....	44	12	28	—18	24	13	26		....	....	....	0.26	— 0.7	7	9,646	nw.	50	nw.	30	7	8	16	6.6	3.2	1.1
St. Paul	837	236	261	29.14	30.08	.00	20.2	+ 0.9	44	12	28	—17	24	13	27		....	....	....	0.27	— 0.8	7	9,596	nw.	60	w.	30	3	13	15	6.8	3.4	0.5
La Crosse	714	11	48	29.27	30.07	— .01	23.5	+ 0.7	50	1	32	—12	25	16	27		....	....	....	1.08	— 0.2	10	4,362	s.	26	sw.	30	7	14	20	7.4	5.7	1.5
Madison	974	70	78	28.97	30.07	— .01	24.4	+ 1.7	51	1	31	— 4	21	18	28		23	21	87	2.73	+ 1.0	12	7,842	nw.	40	w.	30	6	5	20	7.5	6.2	1.0
Wausau	1,247	4	....	28.68	30.04	.....	18.2	.....	40	10	26	—19	25	11	28		....	....	....	1.37	.....	10	.....	nw.	....	....	4	6	21	8.0	12.2	8.9
Charles City	1,015	10	49	28.98	30.10	— .00	24.0	+ 5.0	51	1	32	—12	25	16	29		22	19	84	0.85	— 0.4	4	5,886	nw.	38	nw.	30	6	14	11	6.5	4.7	T.
Davenport	606	71	79	29.40	30.09	— .01	30.4	+ 3.2	54	1	38	5	21	23	23		28	24	79	3.72	+ 2.0	7	6,179	nw.	31	w.	31	6	11	14	6.5	2.8	T.
Des Moines	861	84	97	29.16	30.09	— .02	30.0	+ 4.3	64	13	40	— 5	25	20	30		26	21	72	0.80	— 0.5	6	6,218	n.	28	nw.	30	12	8	11	5.3	1.6	T.
Dubuque	698	81	96	29.31	30.09	— .01	27.2	+ 2.7	54	1	35	— 7	25	20	27		25	22	80	2.43	+ 0.7	6	5,722	nw.	32	nw.	31	5	10	16	6.8	3.8	T.
Keokuk	614	64	78	29.41	30.11	— .01	33.0	+ 3.6	57	11	40	2	25	26	23		29	25	76	2.25	+ 0.4	7	6,622	w.	31	nw.	31	7	14	10	6.1	3.5	0.0
Cairo	356	87	93	29.72	30.11	— .04	42.3	+ 3.8	65	23	50	23	25	34	32		38	33	74	3.02	— 0.3	7	7,669	s.	42	w.	23	8	5	18	6.7	T.	0.0
Peoria	609	11	45	29.40	30.09	— .02	32.2	+ 4.1	55	1	40	9	21	25	34		29	27	88	2.91	+ 0.5	7	6,042	nw.	31	nw.	14	7	7	17	6.6	1.2	T.
Springfield, Ill	644	10	91	29.38	30.08	— .04	34.7	+ 3.4	58	1	42	14	21	28	30		31	29	84	2.71	+ 0.3	8	7,036	w.	29	nw.	31	10	6	15	6.2	1.8	0.0
Hannibal	534	74	109	29.53	30.12	.00	35.0	+ 3.7	59	1	43	6	25	27	27		....	....	....	1.50	— 0.2	7	7,569	sw.	31	nw.	31	12	7	12	5.7	1.0	0.0
St. Louis	567	265	303	29.48	30.10	— .03	38.6	+ 3.1	62	6	46	16	25	31	30		34	29	73	2.89	+ 0.7	6	10,752	s.	43	s.	16	10	6	15	5.7	2.4	0.0
Missouri Valley.							**31.2**	**+ 4.3**											**75**	**0.60**	**— 0.5**									**5.4**		
Columbia, Mo	781	11	84	29.26	30.12	.00	35.5	+ 2.6	63	13	44	7	25	27	26		....	....	....	1.41	— 0.6	6	6,785	sw.	30	nw.	11	10	6	15	6.0	3.7	0.0
Kansas City	963	161	181	29.07	30.13	+ .01	35.9	+ 4.4	69	13	44	7	24	28	30		31	25	68	0.59	— 0.9	6	9,338	sw.	44	nw.	11	11	9	11	5.1	4.8	0.0
St. Joseph	967	11	49	29.05	30.12	.....	34.1	.....	68	13	43	4	24	25	28		29	24	73	0.38	.....	5	6,913	nw.	39	nw.	11	15	8	8	4.5	1.4	T.
Springfield, Mo	1,324	98	104	28.68	30.12	— .01	38.4	+ 2.9	68	13	47	12	25	30	27		34	31	79	1.92	— 0.8	10	8,297	nw.	36	e.	3	13	4	14	5.6	1.1	0.0
Iola	984	11	50	29.05	30.14	+ .02	36.6	+ 4.1	70	13	47	8	25	26	40		....	....	....	0.52	— 0.4	7	5,684	s.	32	ne.	3	8	8	15	6.6	1.2	0.0
Topeka	987	92	107	....	....	....	34.4	+ 3.3	70	13	44	5	24	25	33		....	....	....	0.28	— 0.6	2	8,029	s.	40	nw.	11	12	5	14	5.4	7.3	0.0
Drexel	1,299	10	53	28.69	30.13	.....	29.2	.....	70	13	40	— 8	24	18	38		25	21	78	0.07	.....	3	8,750	nw.	40	nw.	30	12	12	7	4.6	2.0	0.0
Lincoln	1,189	11	84	28.82	30.14	+ .02	31.6	+ 4.7	72	13	43	— 6	24	20	39		27	22	72	0.11	— 0.6	3	8,227	n.	38	nw.	11	16	7	8	4.8	1.5	0.0
Omaha	1,105	115	122	28.92	30.14	+ .03	31.7	+ 4.6	70	13	41	— 5	24	22	36		27	21	69	0.14	— 0.8	2	7,328	nw.	38	nw.	11	13	12	6	4.6	0.8	0.0
Valentine	2,598	47	54	27.35	30.18	+ .08	26.6	+ 2.1	66	13	38	—16	24	15	38		22	19	81	0.74	+ 0.1	4	6,991	w.	55	nw.	30	13	9	9	4.9	11.1	0.0
Sioux City	1,135	94	164	28.89	30.15	+ .03	27.8	+ 5.2	64	13	37	—10	24	19	38		23	18	73	0.31	— 0.4	2	9,050	nw.	53	nw.	30	8	12	11	5.8	4.5	T.
Huron	1,306	59	74	28.72	30.18	+ .08	23.2	+ 7.5	61	13	32	—16	24	14	38		20	16	79	0.42	— 0.2	5	7,060	w.	38	w	4	16	4	11	4.9	4.2	T.
Pierre	1,572	70	75	28.44	30.18	+ .08	25.9	+ 5.8	62	13	34	— 7	24	17	30		22	18	74	0.27	— 0.2	3	6,422	nw.	56	nw.	30	7	13	11	5.8	4.8	T.
Yankton	1,233	49	57	28.77	30.14	+ .03	27.0	+ 4.8	65	13	36	—12	24	18	42		....	....	....	0.60	— 0.1	3	6,527	w.	40	w.	30	8	8	15	6.4	7.0	T

TABLE 1.—*Climatological data for Weather Bureau Stations, December, 1921*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Northern Slope.							23.8	− 0.3										72	1.08	+ 0.2								5.9		
Billings	3,140	5																												
Havre	2,505	11	44	27.45	30.21	+ .16	20.0	− 1.2	55	11	29	−22	20	11	42	17	14	81	0.25	− 0.4	5	6,618	sw.	37	sw.	3	10	9	12	5.9	2.5	T.
Helena	4,110	87	112	25.86	30.23	+ .10	21.9	− 2.9	62	12	30	−17	19	14	27	19	14	73	1.13	+ 0.3	9	4,399	sw.	57	s.	30	5	9	17	6.6	13.0	2.3
Kalispell	2,973	48	56	27.04	30.23	+ .16	21.0	− 2.9	57	12	27	−11	20	15	23	20	16	79	1.16	− 0.7	14	3,515	nw.	24	sw.	12	4	8	19	7.3	6.2	2.4
Miles City	2,371	26	48																											
Rapid City	3,259	50	58	26.66	30.22	+ .13	26.9	+ 0.9	66	12	38	−12	24	16	34	21	15	64	0.70	+ 0.2	6	5,575	w.	46	nw.	30	10	10	11	5.7	7.6	1.0
Cheyenne	6,088	84	101	23.99	30.12	+ .03	30.2	+ 1.2	60	13	41	− 8	24	20	40	25	17	60	1.31	+ 1.0	4	11,465	w.	65	w.	30	13	11	7	4.9	13.5	T.
Lander	5,372	60	68	24.68	30.27	+ .12	18.4	− 0.8	60	13	29	−15	24	7	40	14	10	74	1.67	+ 1.0	7	2,916	sw.	58	sw.	30	12	12	7	5.0	16.7	2.4
Sheridan	3,790	10	47	26.14	30.22	.....	22.6	.....	66	12	34	−12	24	11	35	19	14	74	0.54	.....	8	3,446	s.	44	nw.	30	12	12	7	5.0	6.2	4.2
Yellowstone Park	6,200	11	48	23.88	30.22	+ .06	21.2	− 0.4	43	13	30	−16	19	13	31	19	15	75	2.25	+ 0.4	15	6,337	s.	42	nw.	15	9	3	19	6.9	26.3	16.0
North Platte	2,821	11	51	27.17	30.21	+ .11	30.7	+ 4.1	68	13	44	− 5	24	18	42	24	18	72	0.14	− 0.3	2	5,590	w.	33	n.	16	10	11	10	5.4	1.5	0.0
Middle Slope.							36.1	+ 3.1										68	0.56	− 0.2								5.2		
Denver	5,292	106	113	24.75	30.14	+ .06	35.4	+ 3.2	72	13	47	1	24	24	40	28	20	61	0.85	+ 0.2	4	5,738	s.	46	n.	16	17	10	4	3.7	9.1	0.0
Pueblo	4,685	80	86	25.32	30.12	+ .04	34.2	+ 2.5	71	13	47	− 1	17	22	43	28	22	69	1.12	+ 0.7	5	3,863	nw.	32	w.	12	7	19	5	5.1	11.2	0.0
Concordia	1,392	50	58	28.64	30.16	+ .05	34.3	+ 4.8	75	13	46	0	24	23	41	28	22	70	0.01	− 0.5	1	6,499	nw.	36	nw.	11	12	5	14	5.5	0.1	0.0
Dodge City	2,509	11	51	27.49	30.19	+ .09	33.4	+ 1.8	75	13	45	1	24	21	40	27	23	77	0.68	+ 0.1	2	6,986	nw.	38	n.	3	13	11	7	4.3	6.8	0.0
Wichita	1,358	139	158	28.64	30.12	+ .01	36.6	+ 2.4	75	13	47	7	24	26	35	31	25	68	0.52	− 0.3	4	9,414	n.	42	ne.	2	9	5	17	6.2	3.9	0.0
Altus	1,410	5					44.7	.....	84	13	59	10	25	30	48				0.02	.....	1		n.				16	4	11		T.	0.0
Broken Arrow	765	11	52	29.28	30.12	.....	40.8	.....	76	13	51	14	25	30	38				1.04	.....	6	9,914	n.	40	n.	3	6	6	19	6.8	T.	0.0
Muskogee	652	4					44.0	.....	77	13	55	14	25	33	40				1.62	.....	7		n.				12	10	9			0.0
Oklahoma City	1,214	10	47	28.83	30.14	+ .03	42.7	+ 4.1	79	13	54	10	24	31	37	35	28	64	0.18	− 1.6	5	10,124	n.	37	nw.	17	11	15	5	4.9	0.8	0.0
Southern Slope.							49.1	+ 5.4										49	0.04	− 0.8								4.2		
Abilene	1,738	10	52	28.29	30.13	+ .02	49.6	+ 4.6	81	28	64	15	25	35	45	38	26	47	0.12	− 1.0	1	6,990	s.	35	sw.	2	12	8	11	5.1	0.0	0.0
Amarillo	3,676	10	49	26.32	30.12	+ .03	43.5	+ 7.1	78	13	57	9	24	30	41	34	26	60	0.06	− 0.8	2	8,490	sw.	42	sw.	2	15	10	6	4.2	0.5	0.0
Del Rio	944	64	71	29.12	30.12	+ .02	57.2	+ 4.8	86	2	70	30	5	45	41	.....	.....	.....	T.	− 0.9	0	6,313	se.	40	n.	17	17	7	7	4.2	0.0	0.0
Roswell	3,566	75	85	26.44	30.09	+ .02	46.1	+ 4.9	75	12	62	9	4	30	48	35	20	41	T.	− 0.6	0	5,727	s.	44	nw.	1	17	9	5	3.5	T.	0.0
Southern Plateau.							48.7	+ 3.9										55	0.86	+ 0.4								4.4		
El Paso	3,762	110	133	26.28	30.10	+ .07	49.4	+ 4.6	74	19	60	26	4	38	38	38	26	42	0.15	− 0.4	2	7,724	nw.	49	w.	2	20	8	3	3.1	T.	0.0
Santa Fe	7,013	57	66	23.29	30.14	+ .08	36.6	+ 6.3	58	14	46	9	4	28	30	29	23	65	0.88	+ 0.1	9	5,125	ne.	30	nw.	2	10	9	12	5.3	8.7	0.0
Flagstaff	6,908	10	59																											
Phoenix	1,108	76	81	28.89	30.06	+ .02	56.0	+ 4.1	76	29	68	32	17	44	36	46	38	59	0.87	+ 0.3	4	3,388	e.	34	e.	4	11	12	8	4.9	0.0	0.0
Yuma	141	9	54	29.92	30.06	+ .01	58.0	+ 2.3	76	20	69	39	7	47	34	48	39	58	0.92	+ 0.5	4	4,462	n,	28	n.	16	12	10	9	4.5	0.0	0.0
Independence	3,957	9	41	26.04	30.12	.00	43.6	+ 2.0	68	6	55	24	11	32	37	35	23	51	1.47	+ 1.7	6	4,551	nw.	40	se.	20	16	7	8	4.2	0.5	0.0
Middle Plateau.							35.0	+ 3.7										67	1.66	+ 0.7								5.4		
Reno	4,532	74	81	25.50	30.13	− .02	36.2	+ 2.5	69	12	47	13	17	25	38	30	22	63	2.35	+ 0.7	10	3,580	w.	52	w.	1	11	9	11	5.4	12.6	0.5
Tonopah	6,090	12	20	24.10	30.11	.....	37.5	.....	60	12	44	15	3	31	22	31	21	57	1.08	+ 0.3	6	7,112	se.	48	nw.	2	13	6	12	5.4	2.7	0.0
Winnemucca	4,344	18	56	25.68	30.17	− .01	31.6	+ 0.9	61	13	43	4	17	20	37	27	23	77	1.34	+ 0.4	10	4,702	ne.	48	sw.	1	11	2	18	6.1	15.2	3.8
Modena	5,479	10	43	24.67	30.13	+ .01	34.4	+ 2.7	69	13	46	2	17	22	48	27	19	63	2.14	+ 1.6	8	7,742	w.	46	nw.	2	16	4	11	4.5	5.4	0.0
Salt Lake City	4,360	163	203	25.71	30.16	+ .01	36.4	+ 4.3	58	15	44	17	17	29	33	32	28	72	2.29	+ 1.0	9	4,585	nw.	56	nw.	1	11	7	13	5.5	16.2	0.0
Grand Junction	4,602	60	68	25.49	30.14	+ .04	36.3	+ 8.1	61	21	46	15	17	27	34	31	26	72	0.74	+ 0.3	8	3,429	nw.	28	nw.	16	13	4	14	5.5	1.6	0.0
Northern Plateau.							31.5	− 0.6										78	1.25	− 0.5								7.0		
Baker	3,471	48	53	26.52	30.19	+ .03	30.5	+ 3.1	49	1	37	12	31	24	21	27	24	78	0.97	− 0.6	8	4,005	se.	24	nw.	2	7	5	19	6.6	6.0	T.
Boise	2,739	78	86	27.28	30.21	+ .01	32.9	+ 0.7	51	1	40	15	16	26	27	31	26	75	0.88	− 0.8	9	3,133	nw.	34	sw.	1	7	8	16	6.3	5.3	T.
Lewiston	757	40	48	29.38	30.21	+ .08	34.4	− 3.1	67	12	40	16	20	28	18	.....	.....	.....	0.91	− 0.6	12	2,784	e.	31	w.	2	6	6	19	7.5	2.8	0.3
Pocatello	4,477	60	68	25.54	30.19	.00	30.7	+ 2.3	59	13	39	11	7	23	28	27	23	76	1.97	+ 1.1	14	6,353	se.	44	sw.	1	7	7	17	6.4	15.6	T.
Spokane	1,929	101	110	28.09	30.21	+ .13	29.0	− 1.8	59	12	35	5	19	23	19	27	23	78	1.19	− 1.4	13	4,422	ne.	46	sw.	12	4	9	18	7.1	3.2	1.6
Walla Walla	991	57	65	29.11	30.22	+ .10	31.3	− 4.7	73	12	37	11	22	26	27	29	26	83	1.57	− 0.5	16	2,837	s.	27	sw.	1	4	3	24	8.2	6.4	1.9
North Pacific Coast Region.							39.9	− 2.2										80	5.90	− 1.8								7.3		
North Head	211	11	56	29.83	30.07	+ .04	42.1	− 2.2	62	4	46	24	19	38	19	40	36	79	7.31	− 0.2	14	12,956	e.	90	nw.	1	13	8	10	5.1	1.5	0.0
Port Angeles	29	8	53	30.10	30.14	.....	37.4	.....	62	10	42	15	20	32	18	.....	.....	.....	5.50	+ 0.3	13	5,384	s.	44	n.	18	2	2	27	8.6	3.8	0.0
Seattle	125	215	250	30.00	30.14	+ .13	39.1	− 2.1	57	12	43	19	20	35	16	37	34	81	7.25	+ 1.2	12	7,198	n.	43	sw.	29	4	11	16	7.4	2.5	0.0
Tacoma	213	113	120	29.90	30.13	+ .12	38.4	− 1.9	60	12	43	22	20	33	22	.....	.....	.....	7.36	0.0	15	5,168	ne.	30	ne.	20	1	7	23	8.4	3.5	0.0
Tatoosh Island	86	7	57	29.97	30.07	+ .11	41.8	− 2.1	53	7	45	25	19	39	11	39	35	79	9.30	− 5.3	15	19,818	e.	80	ne.	18	5	11	15	6.8	T.	0.0
Yakima	1,071	4																												
Medford	1,425	4																												
Portland, Oreg.	153	68	106	29.97	30.13	+ .06	39.1	− 2.2	62	12	44	21	19	34	19	36	32	74	3.09	− 4.2	16	5,410	se.	42	w.	1	4	7	20	7.5	4.3	0.0
Roseburg	510	9	57	29.55	30.11	.00	39.0	− 2.9	65	12	44	20	21	34	27	37	36	89	1.52	− 4.4	14	1,643	nw.	40	sw.	1	2	12	17	7.4	2.2	0.0
Middle Pacific Coast Region.							50.0	+ 1.4										78	5.29	+ 0.8								6.0		
Eureka	62	73	89	30.01	30.08	− .04	48.4	+ 0.4	65	4	54	36	3	42	27	46	43	84	4.48	−2.8	14	4,201	se.	48	sw.	1	6	9	16	7.0	0.0	0.0
Mount Tamalpais	2,375	11	18																											
Point Reyes Light	490	7	18	29.49	30.01	.....	51.9	+ 1.3	66	30	56	42	7	48	17	.....	.....	.....	4.12	.....	13	12,966	s.	96	s.	25	8	8	15	6.0	0.0	0.0
Red Bluff	332	50	56	29.71	30.07	− .07	47.9	+ 1.5	67	13	57	28	19	39	31	43	38	72	7.10	+ 2.6	12	4,018	nw.	36	se.	1	10	7	14	5.9	0.0	0.0
Sacramento	69	106	117	30.00	30.07	− .07	49.0	+ 2.7	63	3	56	32	10	42	26	46	42	78	3.81	+ 0.3	12	5,886	se.	50	s.	25	12	9	10	4.8	0.0	0.0
San Francisco	155	208	243	29.89	30.06	− .06	52.9	+ 2.0	66	3	58	44	25	48	16	48	44	77	6.39	+ 2.2	13	6,175	se.	58	sw.	25	10	6	15	6.3	0.0	0.0
San Jose	141	12	110	29.92	30.08	.....	50.1	+ 0.2	68	31	59	32	7	41	30	.....	.....	.....	4.66	+ 1.6	16	4,915	se.	43	s.	25	9	8	14	6.2	0.0	0.0
South Pacific Coast Region.							56.3	+ 3.4										71	6.96	+ 4.8								5.2		
Fresno	327	89	98	29.73	30.10	− .03	50.4	+ 3.0	66	27	59	31	16	42	29	46	42	77	3.47	+ 1.9	13	3,730	nw.	24	se.	20	14	3	14	5.2	0.0	0.0
Los Angeles	338	159	191	29.70	30.07	.00	60.2	+ 3.7	82	10	68	46	23	52	28	52	45	67	7.90	+ 5.0	10	4,930	ne.	43	ne.	3	13	6	12	5.0	0.0	0.0
San Diego	87	62	70	29.96	30.05	− .02	59.3	+ 3.6	79	10	66	46	7	52	31	53	48	72	9.26	+ 7.4	8	4,746	nw.	40	s.	18	10	9	12	5.7	0.0	0.0
San Luis Obispo	201	32	40	29.75	30.06	− .05	55.4	+ 2.6	82	11	66	32	7	44	46	47	41	68	7.22	+ 4.9	11	3,082	s.	26	se.	25	12	8	11	5.1	0.0	0.0
West Indies.																														
San Juan, P. R	82	8	54	29.90	29.99	.....	75.8	.....	87	13	81	68	31	71	15	.....	.....	.....	2.98	− 3.2	19	7,485	e.	30	e.	16	10	16	5	4.6	0.0	0.0
Panama Canal.																														
Balboa Heights	118	7	97	29.74	29.86	− .02	79.9	0.0	89	17	87	71	7	73	18	74	73	84	5.19	+ 1.1	17	4,961	nw.	26	n.	29	0	26	5	5.9	0.0	0.0
Colon	36	7	97	29.83	29.87	+ .02	80.6	+ 0.8	87	23	85	73	1	76	12	75	74	80	6.50	− 4.8	25	9,816	n.	32	n.	28	2	17	12	6.7	0.0	0.0
Alaska.																														
Juneau	80	11	49	.....	.....	.....	34.6	.....	51	7	38	20	23	31	19	32	30	86	12.68	.....	22	3,457	se.	26	se.	7	6	3	22	7.7	21.4	9.1

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December, 1921.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*In.*	*In.*	*In.*	*°F*	*°F*	*°F*	*°F*	*°F*	*°F*	*In.*	*In.*	*In.*
St. Johns, N. F	125	29.45	29.59	−.24	29.8	+ 1.1	34.8	24.9	54	12	6.61	+1.58	3.0
Sydney, C. B. I	48	29.76	29.81	−.07	28.6	+ 0.4	33.9	23.2	49	7	5.10	+0.47	31.1
Halifax, N. S	88	29.73	29.84	−.12	27.3	− 0.3	34.9	19.7	52	4	3.56	−1.56	18.3
Yarmouth, N. S	65	29.80	29.87	−.11	31.0	+ 0.3	37.3	24.7	51	6	3.17	−1.87	8.5
Charlottetown, P. E. I	38	29.79	29.83	−.11	24.7	+ 0.4	30.5	19.0	44	1	4.38	+0.72	31.6
Chatham, N. B	28	29.84	29.87	−.06	19.3	+ 2.3	27.2	11.5	51	−11	1.91	−1.31	13.5
Father Point, Que	20	29.86	29.89	−.06	16.6	+ 1.2	23.0	10.2	38	13	1.68	−1.15	10.0
Quebec, Que	296	29.59	29.93	−.08	15.1	− 0.1	21.7	8.6	39	−18	3.85	+0.16	16.3
Montreal, Que	187	29.74	29.96	−.07	19.1	+ 0.8	25.6	12.7	48	−11	2.56	−1.09	13.5
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.70	29.98	−.04	18.5	+ 1.5	26.5	10.6	46	−14	2.47	−0.44	10.7
Kingston, Ont	285	29.67	30.01	−.03	24.8	+ 1.1	32.9	16.8	50	− 8	2.18	−1.06	5.0
Toronto, Ont	379	29.57	30.00	−.05	28.3	+ 1.3	35.4	21.3	52	0	2.40	−0.51	6.8
Cochrane, Ont	930												
White River, Ont	1,244	28.55	29.93	−.04	8.0	− 1.7	20.3	−4.3	39	−45	1.58	−0.13	15.8
Port Stanley, Ont	592	29.36	30.02	−.05	28.8	+ 0.4	36.2	21.4	51	2	3.23	+0.81	14.5
Southampton, Ont	656	29.24			27.6	+ 0.9	34.1	21.1	53	3	4.26	+0.28	17.1
Parry Sound, Ont	688	29.22	29.95	−.06	20.9	− 0.3	30.5	11.3	45	−16	4.83	+0.35	32.8
Port Arthur, Ont	644	29.26	29.99	.00	15.7	+ 2.5	22.8	8.5	38	−22	0.66	−0.21	6.6
Winnipeg, Man	760	29.18	30.06	+.04	11.4	+ 7.3	20.0	2.9	36	−26	0.50	−0.41	5.0
Minnedosa, Man	1,690	28.16	30.08	+.06	10.7	+ 5.0	19.8	1.6	40	−30	0.23	−0.39	2.3
Le Pas, Man	860												
Qu'Appelle, Sask	2,115	27.72	30.07	+.07	13.2	+ 5.8	21.5	5.0	42	−32	0.61	+0.09	2.1
Medicine Hat, Alb	2,144												
Moose Jaw, Sask	1,759												
Swift Current, Sask	2,392	27.47	30.07	+.08	17.9	+ 1.9	26.1	9.8	50	−24	0.19	−0.59	1.5
Calgary, Alb	3,428												
Banff, Alb	4,521												
Edmonton, Alb	2,150												
Prince Albert, Sask	1,450	28.44	30.07	+.06	8.9	+ 6.1	17.4	0.4	42	−36	0.40	−0.34	4.0
Battleford, Sask	1,592	28.26	30.10	+.11	9.8	+ 4.4	18.8	0.8	45	−32	0.20	−0.12	2.0
Kamloops, B. C	1,252				18.8	−10.1	24.0	13.6	49	−14	0.47	−0.31	4.2
Victoria, B. C	230	29.86	30.12	+.15	37.8	− 3.4	41.7	33.9	56	16	5.57	−2.41	0.9
Barkerville, B. C	4,180	25.60	30.07	+.19	13.1	− 7.8	20.9	5.3	40	−27	1.10	−2.07	11.0
Triangle Island, B. C	680												
Prince Rupert, B. C	170												
Hamilton, Ber	151	29.92	30.09	−.03	64.4	− 0.3	70.2	58.6	77	51	6.67	−2.18	0.0

SEISMOLOGICAL REPORTS FOR DECEMBER, 1921.

W. J. HUMPHREYS, Professor in Charge

[Weather Bureau, Washington, Feb. 3, 1922.]

TABLE 1.—*Noninstrumental earthquake reports, December, 1921.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
1921.	*H. m.*	CALIFORNIA.	° ′	° ′			*Sec.*			
(Dec. 2	19 30	Calexico	32 41	115 30	2	1	10	None	Felt by several	W. S. Pratt.
		WYOMING.								
6	12 30	Grover	42 45	110 50	3-4	3	.....	Rumbling	Felt by several	C. J. Hepworth.

TABLE 2.—*Instrumental seismological reports, December, 1921.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols, see REVIEW for January, 1921, p. 47.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*								
1921 Dec. 18		P_E	*H. m. s.* 15 40 43	*Sec.* 4	μ	μ	*Km.*	No L waves evident; M occurs during S.
		P_N	15 40 49					
		S	15 49 47					
		M_E	15 49 58		50			
		M_N	15 50 11			60		
		F	15 59 ..					
ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*								
1921 Dec. 18		P_N	*H. m. s.* 15 37 38	*Sec.* 4	μ	μ	*Km.*	Recorded on magnetogram at 15h45m; no L waves evident; M occurs during S; E component not operating.
		S_N	15 44 23	7				
		M_N	15 44 37			360		
		F_N	16 07 ..					
COLORADO. *Regis College, Denver.*								
1921 Dec. 18		P	*H. m. s.* 15 37 ..	*Sec.* N, 4; E, 5	μ	μ	*Km.*	S not discernible.
		L	15 44 ..	N, 4; E, 5				
		M	15 44 ..		*8,000	*10,400		
		C	15 52 ..					
		F	16					
DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*								
1921 Dec. 18		P	*H. m. s.* 15 36 41	*Sec.*	μ	μ	*Km.* 3,700	L indiscernible.
		S	15 42 12					
		M	15 42 30		*24,000			
		F	16 35 ..					
*Trace amplitude.								
ILLINOIS. *U. S. Weather Bureau, Chicago.*								
1921 Dec. 18		P	*H. m. s.* 15 36 08	*Sec.*	μ	μ	*Km.* 4,400	Record complex.
		S	15 42 20					
		M_E	15 42 30		*15,000			L not discernible.
		M_E	15 45 ..		*15,000			
		F	18 *ca* ..					
MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*								
1921. Dec. 18		P	*H. m. s.* 15 36 42	*Sec.* 3	μ	μ	*Km.*	Heavy micros.
		S_E	15 42 22					No L waves evident; M occurs during S.
		iS_N	15 42 13	8				
		M_E	15 42 34		210			
		M_N	15 42 46	9		150		
		F_E	16 07 ..					
		F_N	16 15 ..					
MISSOURI. *St. Louis University, St. Louis.*								
1921. Dec. 18		iP	*H. m. s.* 15 37 03	*Sec.*	μ *4,000	μ *7,000	*Km.* 2,700	P very violent.
		iS	15 40 06?					
		iL	15 43 00					
		M	15 43 03	6	*40,000	*55,000		
		F	16 28 00					

Date.	Character.	Phase.	Time.	Period T.	Amplitude A_E	Amplitude A_N	Distance.	Remarks.
NEW YORK. *Fordham University, New York.*								
1921. Dec. 18		P_E	*H. m. s.* 15 36 57	*Sec.*	μ	μ	*Km.*	
		P_N	15 36 51					
		(PR1)	15 38 48					
		(PR2)	15 39 48					
		S_E	15 42 48					
		S_N	15 42 42					
		L_N	15 45 30					
		M_N	15 45 48					
CANAL ZONE. *Panama Canal, Balboa Heights.*								
1921. Dec. 18		P_E	*H. m. s.* 15 32 46	*Sec.*	μ	μ	*Km.* 1,530*ca.*	Probably SW.
		P_N	15 32 40					
		S_E	15 35 10					
		S_N	15 35 20					
		L_E	15 36 38					
		L_N	15 36 52					
		M_E	15 35 44		*50,000			
		M_N	15 37 48			*37,000		
		F_E	16 07 30					
		F_N	16 11 00					
23		P_E	2 05 02				70*ca.*	Probably W. or SW.
		P_N	2 05 00					
		S_E	2 05 10					
		S_N	2 05 08					
		M_E	2 05 12		*6,500			
		M_N	2 05 14			*5,000		
		F_E	2 07 10					
		F_N	2 07 00					
*Trace amplitude.								
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*								
1921. Dec. 18		P	*H. m. s.* 15 33 50	*Sec.*	μ	μ	*Km.*	Heavy micros.
		S	15 37 25					No L waves evident; M occurs during S.
		M	15 37 28		250	500		
		F_E	16 19					
		F_N	16 02					
22		P_E	20 43 43				400	
		P_N	20 43 32					
		L	20 44 23	8				
		M_E	20 44 44		100			
		M_N	20 44 56			60		
		C_E	20 45 46					
		C_N	20 45 08					
		F	20 50					
VERMONT. *U. S. Weather Bureau, Northfield.*								
1921. Dec. 18		P	*H. m. s.* 15 37 15	*Sec.*	μ	μ	*Km.*	
		S	15 43 35					
		F	16 15					
CANADA. *Dominion Observatory, Ottawa.*								
1921. Dec. 18		O	*H. m. s.* 15 29 27	*Sec.*	μ	μ	*Km.* 4,620	
		P	15 37 29					
		i[illegible]	15 40 29					
		S	15 43 50					
		SR1?	15 46 14					
		eL	15 49					Irregular L waves.
		F	17 31 *ca*					

TABLE 2.—*Instrumental seismological reports, December, 1921*—Con.

CANADA. *Dominion Meteorological Service, Toronto.*

1921.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 8	.....	L	13 24 48	.....	.....	.....	.....	Heavy micros going on.
		eL	13 28 36	.....	.....	.....	.....	
		M	13 31 00	.....	*300	.....	.....	
		F	.....	.....	.....	.....	.....	Micros.
18	.....	L	10 58 18	.....	.....	.....	.....	
		M	11 02 24	.....	*300	.....	.....	
		F	11 07 36	.....	.....	.....	.....	
18	.....	P	15 37 48	.....	.....	.....	5,000	P very small and poorly defined; S and SR large came in abruptly. Possibly Iceland.
		PR	15 41 30	.....	.....	.....	.....	
		iS	15 44 30	.....	*1,800	.....	.....	
		iSR	15 47 30	.....	*2,300	.....	.....	
		M	15 48 30	.....	*2,500	.....	.....	
		eL	15 50 30	.....	.....	.....	.....	
		eL	15 58 12	.....	.....	.....	.....	
		L	15 58 54	.....	.....	.....	.....	
		F	.....	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Victoria.*

1921.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 7	.....	M	18 31 33	.....	*200	.....	.....	
8	.....	L	12 51 07	.....	.....	.....	.....	
		M	13 19 39	.....	*200	.....	.....	
		F	13 53 05	.....	.....	.....	.....	
18	.....	L	10 46 42	.....	.....	.....	.....	
		M	10 53 35	.....	*450	.....	.....	
		F	11 00 58	.....	.....	.....	.....	
18	.....	P	15 38 20	.....	.....	.....	.....	
		S	15 41 17	.....	.....	.....	.....	iL may be S phase.
		iL	15 47 11	.....	.....	.....	.....	
		eL	16 04 00	.....	.....	.....	.....	
		M	16 04 54	.....	*1,500	.....	.....	
		F	17 39 19	.....	.....	.....	.....	
22	.....	L	21 12 40	.....	.....	.....	.....	
		M	21 18 04	.....	*1,500	.....	.....	
		F	21 25 56	.....	.....	.....	.....	
31	.....	L	0 06 54?	.....	.....	.....	.....	
		M	0 11 19	.....	*100	.....	.....	

*Trace amplitude.

No reports for December, 1921, have been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

CALIFORNIA. *Theosophical University*, Point Loma.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

HAWAII. *U. S. C. & G. S. Magnetic Observatory*, Honolulu.

MASSACHUSETTS. *Harvard University*, Cambridge.

NEW YORK. *Canisius College*, Buffalo; *Cornell University*, Ithaca.

EARTHQUAKES FELT IN THE UNITED STATES DURING 1921.

[Consult also chart XIII in this issue.]

During the year 1921, 83 separate earthquakes strong enough to be felt by the unaided senses were reported from different parts of the continental United States, as listed in the accompanying table, and graphically represented (a dot for each *report*, not for each separate quake) on chart XIII at the end of this issue of the REVIEW.

Earthquakes of reported intensity 5 (adapted Rossi-Forel scale), not accompanied by appreciable damage, occurred in Arizona on April 6; in California on January 13, 14, July 25, August 10, September 29, November 17; in Colorado on February 6; in Oregon on February 25; in Tennessee on December 15; and in Virginia on August 7.

Shocks of intensity 5, the origin of which is somewhat uncertain, created considerable excitement in New Jersey on January 26. Widespread quakes, resulting in a moderate amount of damage, took place in Utah in September, the latter part of October, and the first of November.

Places in the United States reporting earthquakes during 1921.

[Consult also Chart XIII in this issue.]

Place.	Approximate latitude N.	Approximate longitude W.	Number of quakes reported.
ARIZONA.	° ′	° ′	
Holbrook	34 55	110 05	1
Pinto	35 05	109 30	1
St. Michaels	35 40	109 05	1
Yuma	32 40	114 35	2
CALIFORNIA.			
Aguanga	33 30	117 00	1
Bakersfield	35 22	119 00	1
Blythe	33 40	114 45	1
Calexico	32 41	115 30	10
Calipatria	33 08	115 30	1
Campbell	37 14	121 53	1
Centerville	37 30	122 00	1
Claremont	37 48	122 26	1
Eureka	40 48	124 10	4
Hollister	36 45	121 20	1
Idria	36 24	120 42	1
Julian	33 05	116 37	2
Lone Pine	36 37	118 01	3
Los Angeles	34 03	118 15	1
Los Gatos	37 12	121 58	1
Maricopa	35 05	119 23	1
Mount Wilson	34 13	118 16	1
Ontario	34 05	117 40	1
Pomona	34 05	117 45	2
Pot Holes	32 50	114 40	1
Redlands	34 04	117 12	1
Riverside	33 58	117 21	2
Salinas	36 41	121 39	3
San Bernardino	34 05	117 15	1
San Diego	32 40	117 10	1
San Francisco	37 48	122 26	1
San Jacinto	33 45	117 00	1
San Jose	37 15	121 53	2
Santa Clara	37 15	121 55	2
Spreckles	36 38	121 36	1
Susanville	40 30	120 45	1
Trona	35 45	117 20	2
Venice	33 58	118 28	2
Watsonville	36 50	121 30	1
Willows	34 03	118 15	1
Wrights	34 03	118 15	1
COLORADO.			
Eads	38 30	102 50	1
Garfield	38 37	106 20	12
St. Elmo	38 45	106 20	2
ILLINOIS.			
Cairo	37 00	89 05	1
Chester	37 50	89 50	1
Danville	40 07	87 40	1
Decatur	39 50	89 00	1
Hoopeston	40 30	87 45	1
Kanakee	41 05	87 05	1
Olney	38 45	88 10	1
Paris	39 40	87 40	1
Salem	38 40	89 00	1
Tuscola	39 50	88 30	1
Urbana	40 07	88 15	1
Waterloo	38 20	90 12	4
INDIANA.			
Crawfordsville	40 07	86 50	1
Indianapolis	39 50	86 10	1
Mount Vernon	37 55	87 55	1
Noblesville	40 05	86 00	1
Princeton	38 25	87 35	1
Rockville	39 50	87 10	1
Terre Haute	39 30	87 25	1
Veedersburg	40 10	87 15	1
Vincennes	38 42	87 30	1
KENTUCKY.			
Hickman	36 34	89 12	1
MAINE.			
Eastport	45 00	67 00	1
MISSOURI.			
New Madrid	36 35	89 32	1
NEW JERSEY.			
Atsion	39 45	74 45	1
Burlington	40 05	74 50	1
Moorestown	75 00	39 55	1
Palmyra	75 00	40 00	1
Riverside	75 00	40 05	1
Riverton	75 00	40 00	1

Places in the United States reporting earthquakes during 1921—Continued.

Place.	Approximate latitude N.	Approximate longitude W.	Number of quakes reported.
NEW MEXICO.	° ′	° ′	
Senorito	36 00	107 00	1
OREGON.			
Cascadia	44 20	122 30	1
Portland	45 30	122 40	2
PENNSYLVANIA.			
Erie	42 05	80 10	1
SOUTH CAROLINA.			
Summerville	33 05	80 15	2
SOUTH DAKOTA.			
Sioux Falls	43 30	96 45	1
White Lake	43 45	99 00	1
TENNESSEE.			
Statesville	36 10	86 15	1
Tiptonville	36 24	89 30	1
UTAH.			
Cedar City	37 40	113 00	1
Greenwich	38 30	111 50	1
Joseph	38 40	112 00	1
Kanosh	38 50	112 20	1
Richfield	38 45	112 00	2
VIRGINIA.			
Buckingham	37 35	78 35	1
Columbia	37 45	78 10	1
Covesville	37 50	78 50	1
Dillwyn	37 40	78 30	1
New Canton	37 40	78 20	1
Scottsville	37 45	78 30	1
Warren	37 45	78 40	1
WYOMING.			
Grover	42 45	119 50	1

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

Forecast Division. *Washington, D. C., March 1, 1922.*

DISTRIBUTION OF WEATHER INFORMATION, FORECASTS, AND WARNINGS BY NAVAL RADIO FOR THE BENEFIT OF MARINE AND AVIATION INTERESTS ON THE PACIFIC COAST.

(In cooperation with Office of Communications, Navy Department.)

Beginning March 15, 1922, the Weather Bureau will issue daily (Sundays and holidays included) bulletins containing weather reports, forecasts, and warnings for the benefit of marine and aviation interests in the coastal waters of the Pacific and in the States bordering on that ocean. These bulletins will be broadcast from Naval Radio stations and will supersede all service of a similar character announced in Navy Department and Weather Bureau regulations and circulars.

MAJOR BULLETINS.

They will be broadcast from the San Francisco Naval Radio Station (call letters NPG) twice daily as follows:

Morning bulletin at NOON (75th meridian time); wave length, 4,650 meters, CW.

Evening bulletin at 10:30 p. m. (75th meridian time); wave length, 1,908 meters, AR (Spark).

The bulletins are divided into two parts and invariably begin with the letters USWB (U. S. Weather Bureau). The first part consists of surface weather conditions based upon observations taken at 8 a. m. and 8 p. m., 75th meridian time (except at Alaskan stations and Honolulu, T. H., which are taken at 8 a. m. and 8 p. m. 135th meridian and local time respectively), and of upper air observations taken in the afternoon of the date of distribution. The second part of the bulletin consists of synopsis of general atmospheric pressure distribution, including the locations of High and Low areas, and the barometer readings at their centers; wind and weather forecasts for Pacific offshore areas; storm warnings for these areas; and flying weather forecasts for each of three aviation zones (chart on page 4).

FIRST PART.

Key-letters and stations.

	*Alaska.**		*United States*—Contd.
DH	Dutch Harbor.	DI	†San Diego, Calif.
EA	Eagle.	HL	Helena, Mont.
JU	Juneau.	BS	Boise, Idaho.
NM	Nome.	LD	Lander, Wyo.
SK	Sitka.	WM	Winnemucca, Nev.
TN	Tanana.	R	Reno, Nev.
VZ	Valdez.	SLC	Salt Lake City, Utah.
	United States.	MD	Modena, Utah.
TAT	Tatoosh Island, Wash.	DV	Denver, Colo.
SE	†Seattle, Wash.	GJ	Grand Junction, Colo.
NH	North Head, Wash.	SA	Santa Fe, N. Mex.
PD	Portland, Oreg.	PH	Phoenix, Ariz.
RO	Roseburg, Oreg.	YU	Yuma, Ariz.
EUR	Eureka, Calif.	HO	Honolulu, T. H.
RB	Red Bluff, Calif.		*Canada.*
SM	†Sacramento, Calif.	ED	Edmonton, Alberta.
SF	†San Francisco, Calif.	KA	Kamloops, B. C.
FN	Fresno, Calif.	CY	Calgary, Alberta.
SLO	San Luis Obispo, Calif.	SC	Swift Current, Sask.
LA	†Los Angeles, Calif.	PR	Prince Rupert, B. C.

*Alaskan reports included in a. m. bulletin are observations taken previous p. m.; those in p. m. bulletins are observations taken a. m. current date.

†Stations with which upper air observations are included in the p. m. bulletin regularly; and in the noon bulletin when obtained in time.

The stations are indicated by one or more key-letters which are followed by two or more 5-unit groups of figures. The first two groups are always surface observations taken at the stations indicated by the key-letters. Additional groups containing upper air data are included only in the reports from stations marked with a dagger (†), and invariably are represented in the third and succeeding 5-unit groups.

The letter "X" will be substituted for any missing data.

When upper air observations are not possible because of dense fog, rain or snow the word FOGGY, RAIN, or SNOW, as the case may be, will be sent instead of the third group.

The names of the aerological stations are not included in the bulletin. Observations therefrom are made a part of the report of the nearest regular Weather Bureau station. The location of the aerological stations, the service that conducts them, and the surface stations with which the data are coded are as follows:

Aerological stations.	Conducted by	Surface stations, with which upper air reports are included.
North Island, Calif.	U. S. Navy	San Diego, Calif.
Ross Field, Calif.	Signal Corps, U. S. A.	Los Angeles, Calif.
San Francisco, Calif.	U. S. Weather Bureau	San Francisco, Calif.
Mather Field, Calif.	Signal Corps, U. S. A.	Sacramento, Calif.
Camp Lewis, Wash.	Signal Corps, U. S. A.	Seattle, Wash.

SECOND PART.

The second part of the bulletin is in plain language and consists of a synopsis of general pressure distribution; wind and weather forecasts for ocean zones (see chart page 4) for a period of 24 hours beginning at noon day of issue; storm warnings; and flying weather forecasts by zones (see chart page 4) for a period noon to midnight of day of issue.

EXPLANATION OF GROUPS.

First group (surface).—*Barometric pressure* reduced to sea-level and expressed in three figures; *wind direction* expressed in one figure; and *wind force* (Beaufort scale) expressed in one figure.

Second group (surface).—*State of weather* expressed in one figure; *barometric tendency* (rise or fall in hundredths of an inch during two hours immediately preceding the observation) expressed in one figure; and *clouds* expressed in three figures, indicating, in order, the amount of the clouds (tenths of sky that is covered), the kind of clouds, and the direction of cloud movement.

Barometric tendency reports are not received from all stations and no cloud reports from the Alaskan, Canadian, and some United States stations. The missing data in this group will be represented by the appropriate number of X's.

Third group (upper air).—Two levels are included in this group, 250 meters and 500 meters. The first figure (3) identifies the group; the second figure indicates the wind direction at the lower elevation and the third figure the wind force at the lower elevation; the fourth and fifth figures represent, respectively, the wind direction and force at the higher elevation.

Fourth group (upper air).—Includes 1,000 and 1,500 meter elevations; same arrangement of the five significant figures as in the third group.

Fifth group (upper air).—Includes 2,000 and 3,000 meter elevations; same arrangement of the five significant figures as in the third group.

Sixth group (upper air).—Includes 4,000 meter elevation; same arrangement, as in the third group, except that there will be only three figures in this group, followed by XX, as elevations in excess of 4,000 meters are reported only in the last group.

Last group (upper air).—Shows the highest elevation reached. The first figure (7) identifies the group as the one showing the maximum altitude, (it may be the fourth, fifth, sixth, or seventh group, dependent upon the actual elevation reached); the second and third figures indicate the elevation

in hundreds of meters; the fourth and fifth figures wind direction and velocity, respectively, at the indicated elevation. When the maximum elevation is 9,900 meters or more the figures 99 will be used.

KEY TO GROUPS AND EXAMPLES.

First group.

Barometric pressure (first three figures of group): Actual pressure in inches and hundredths used, except that first figure of full reading is omitted. Thus, if the actual corrected pressure is 29.98 inches, the figures 998 are sent, or if the reading is 30.14 inches, the figures 014 are sent.

Direction of surface wind (fourth figure of group).

0=calm or no movement.
1=north. 5=south.
2=northeast. 6=southwest.
3=east. 7=west.
4=southeast. 8=northwest.

Force of wind (fifth figure of group): Sent according to Beaufort scale values 0 to 9, inclusive.

Beaufort Scale.

Scale number.	Designation.	Miles.	
		Statute.	Nautical.
0	Calm	0-3	0-3
1	Light air	3-8	3-7
2	Light breeze	8-13	7-11
3	Gentle breeze	13-18	11-16
4	Moderate breeze	18-23	16-20
5	Fresh breeze	23-28	20-24
6	Strong breeze	28-34	24-30
7	Moderate gale	34-40	30-35
8	Fresh gale	40-48	35-42
9	Strong gale	48-56	42-49
‡Ten	Whole gale	56-65	49-56
‡Eleven	Storm	65-75	56-65
‡Twelve	Hurricane	75	65

‡NOTE.—The code does not admit of force in excess of 9 being sent. Therefore, the figure 9 will be used for all wind forces 9 to twelve inclusive.

Example of first group as sent: 99852.

Translation: Barometric pressure, 29.98 inches, wind from south, wind force, 2 (8 to 13 statute miles per hour).

Second group.

Present weather (first figure of group): State of weather at surface at 8 a. m., 75th meridian time.

1=clear (3 tenths or less). 5=snowing.
2=partly cloudy (4 to 7 tenths). 6=thunder-storm.
3=cloudy (8 to 10 tenths). 7=sleeting or hailing.
4=raining. 8=dense fog.

Pressure change (second figure of group) in hundredths of inch during two hours preceding observation.

0=change of less than .04 inch.
1=increase of .04.
2=decrease of .04.
3=increase of .06.
4=decrease of .06.
5=increase of .08.
6=decrease of .08.
7=increase of .10.
8=decrease of .10.
§9=increase or decrease of .12 or more.

§NOTE—Whether it is an increase or decrease can be determined by barometric tendency shown at surrounding stations.

Amount of clouds (third figure of group): Number of tenths of the sky obscured (10 tenths is total cloudiness).

0=1 tenth or less of sky covered.
2=2 to 3 tenths of sky covered.
4=4 to 5 tenths of sky covered.
6=6 to 7 tenths of sky covered.
8=8 to 10 tenths of sky covered.

Kinds of clouds (fourth figure of group).

0=1 tenth clouds or less (kind not indicated).
1=upper clouds (cirrus, cirro-stratus, cirro-cumulus, alto-cumulus, or alto-stratus), rapidity not indicated.
2=strato-cumulus moving slowly.
3=strato-cumulus moving rapidly.
4=cumulus moving slowly.
5=cumulus moving rapidly.
6=stratus moving slowly.
7=stratus moving rapidly.
8=nimbus or cumulo-nimbus moving slowly.
9=nimbus or cumulo-nimbus moving rapidly.

Direction of cloud movement (fifth figure of group).

0=no movement observable.
1=north. 5=south.
2=northeast. 6=southwest.
3=east. 7=west.
4=southeast. 8=northwest.

When both upper and lower clouds are observed, only the amount, kind, and direction of the lower clouds will be sent. In such cases the amount of the upper clouds, if any, can be determined approximately by taking the difference between the tenths of cloudiness interpreted from the figures showing "present weather" and "amount of clouds".

Example of second group as sent: 30855.

Translation: Cloudy weather; pressure change less than .04 inch during preceding two hours; 8 to 10 tenths clouds; cumulus clouds moving rapidly from the south.

The upper air observations are included in five groups and have identifying numbers 3 to 7, inclusive. The wind direction and force are indicated by the same numerals as for surface wind direction and force.

Third group.

(Five figures) 250 and 500 meter levels. The identifying figure for this group is 3, and is always the first figure of the group. The second figure is direction of wind at 250 meters and the third figure is wind force at 250 meters. The fourth figure is wind direction at 500 meters and the fifth figure is wind force at 500 meters.

Example: 35163.

Translation: Observations at 250 and 500 meter levels; wind blowing from south with force 1 (3 to 8 statute miles per hour) at 250 meters; wind blowing from southwest with force 3 (13 to 18 statute miles per hour) at 500 meters.

Fourth group (1,000 and 1,500 meters), Fifth (2,000 and 3,000 meters), and Sixth (4,000 meters) have the same arrangement as group three, except that group six will have only three figures followed by XX, the first figure, 4, 5, and 6, respectively, always identifying the group.

Last group (highest elevation reached). The first figure (7) identifies the group; the second and third figures indicate the elevation in multiples of 100 meters; the fourth and fifth figures show wind direction and force, respectively, at that elevation.

Examples: (*a*) 71785, (*b*) 71954, (*c*) 79979.

Translation:

(*a*) Highest elevation reached, 1,700 meters; wind blowing from northwest with force 5 (23 to 28 statute miles).

(*b*) Highest elevation reached, 1,900 meters; wind blowing from south with force 4 (18 to 23 statute miles).

(*c*) Highest elevation reached, 12,000 meters; wind blowing from west with force 9 (48 to 56 statute miles).

PERIOD COVERED BY FORECASTS.

In a. m. bulletins:

Wind and weather forecasts; 24 hours beginning at noon, 75th meridian time.

Flying weather forecasts; 12 hours, noon until midnight, 75th meridian time.

In p. m. bulletins:

Wind and weather forecasts; 24 hours, beginning at midnight, 75th meridian time.

Flying weather forecasts; 12 hours, midnight until noon next day, 75th meridian time.

EXAMPLE OF MAJOR BULLETINS.

First part as sent.

DH 9526X 50XXX EA 9587X 3XXXX JU 98431 43XXX NM 96871 1XXXX SK 9448X 30XXX TN 9767X 5XXXX VZ 9126X 51XXX TAT 98045 44884 SE 99842 44884 Rain NH 99058 44885 PD 01051 32865 RO 02241 30864 EUR 03041 80864 RB 03000 30850 SM 03241 10000 32112 41312 582XX 72882 SF 03251 10000 32021 41214 51414 62425 73314 FN 03281 30868 SLO 03081 30827 LA 01821 10000 37272 46152 53324 615XX 77517 DI 01421 10000 38181 46243 52215 73816 HL 01262 50887 BS 03200 10000 LD 03251 20666 WM 03811 10000 R 03412 20417 SLC 02641 50867 MD 03072 20417 DV 02652 10000 GJ 01831 10000 SA 01212 10218 PH 01221 10000 YU 01811 10000 ED 99081 12XXX KA 00231 1XXXX CY 99071 1XXXX SC 01651 20XXX PR 94844 3XXXX HO 00434 4XXXX.

Second part as sent.

Storm central north of British Columbia, moving east. Lowest barometer 29.48 inches at Prince Rupert. Area of high barometer central over Nevada moving slowly southeast. Highest barometer 30.38 inches at Winnemucca. The evening of the 4th a storm of marked intensity was central near Valdez and moving eastward, with lowest barometer at its center 29.12 inches, and another disturbance moving eastward over western Aleutian Islands.

Winds north Pacific coast will be strong southerly, with gales and rain. Winds south Pacific coast will be moderate variable mostly southerly, with fair weather. Southeast storm warnings ordered 7:10 a. m. for Washington and Oregon coasts.

Zone twelve: Generally clear sky and moderate southerly winds, surface and aloft. Zone thirteen: Low clouds, rain and southerly gales, surface and aloft. Zone fourteen: Generally clear skies and moderate winds mostly southerly, surface and aloft.

LOCAL BULLETINS.

The table below shows the naval radio stations from which distributions are made daily (including Sundays and holidays), their transmitting wave lengths, call letters, the information broadcast therefrom, the hours of distribution (75th meridian time), and the Weather Bureau stations from which the forecasts and information are supplied.

Whenever storm warnings are issued in the forenoon (based on 8 a. m. observations) they are broadcast at the same time as the wind and weather forecasts. When issued in the afternoon (based on special observations) or at night (based on 8 p. m. observations) they are broadcast at the evening hours indicated.

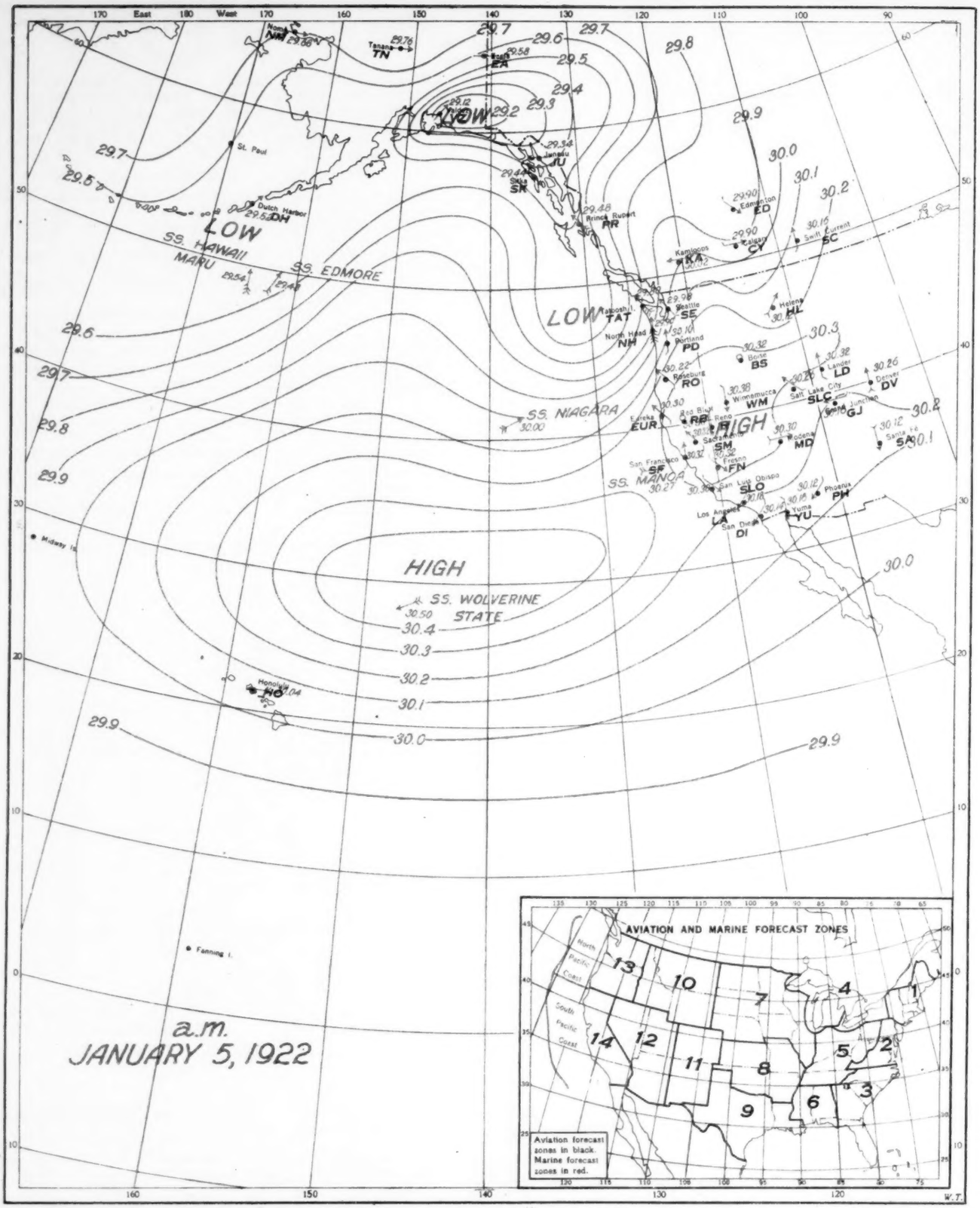
Ships may request any station listed herein to furnish the latest weather forecasts and warnings and weather reports.

Forecasts broadcast at or before noon and in the p. m. are for the 24 hours beginning at noon and midnight, respectively; storm warnings are for 24 hours beginning at the hour indicated in the warnings messages.

Storm warnings are displayed at 45 points on the Pacific coast of the United States. Flags are used by day and lanterns by night.

Cards descriptive of storm signals and a copy of this bulletin will be furnished free on application to any U. S. Weather Bureau office on the Pacific coast.

Naval radio stations.			Weather information broadcast.	Broadcasting time (75th meridian), except as indicated.	Weather Bureau stations issuing information.
Location.	Transmitting wave.	Call letters.			
Tatoosh Island, Wash.	1,654	NPD	(*a*) Wind and weather forecasts and storm warnings for Washington coast and Puget Sound; advices concerning storm warnings issued for north Pacific coast.	(*a*) Noon and 11 p. m.	Tatoosh Island, Wash.
			(*b*) Current barometric pressure, wind direction and velocity, and state of weather at Tatoosh Island.	(*b*) 8 a. m.; noon, 4 p. m., 8 p. m., and 11 p. m.	
			(*c*) Storm warnings and advices issued in afternoon.....	(*c*) 4 p. m. and 8 p. m.	
			(*d*) Reports of fog in Strait of Juan de Fuca.....	(*d*) 8 a. m.; noon, 4 p. m. and 8 p. m.	
North Head, Wash.	2,700	NPE	(*a*) Wind and weather forecasts and storm warnings for Washington and Oregon coasts and mouth of Columbia River; advices concerning storm warnings issued for north Pacific coast.	(*a*) 12:30 a. m.; 11:30 p. m.	North Head, Wash.
			(*b*) Current barometric pressure, wind direction and velocity, and state of weather at North Head.	(*b*) 8:30 a. m.; 12:30 p. m., 4:30 p. m., 8:30 p. m., 11:30 p. m.	
			(*c*) Storm warnings and advices issued in afternoon.....	(*c*) 4:30 p. m. and 8:30 p. m.	
Eureka, Calif.....	2,650	NPW	(*a*) Wind and weather forecasts and storm warnings for California coast north of San Francisco; advices concerning storm warnings for north Pacific coast.	(*a*) Noon	Eureka, Calif.
			(*b*) 8 a. m. and 8 p. m. barometric pressure, wind direction and velocity, and state of weather at Eureka.	(*b*) Noon and 8:30 p. m., respectively.	
			(*c*) Storm warnings issued in the afternoon.....	(*c*) 5 p. m. and 8:30 p. m.	
San Pedro, Calif....	1,851	NPX	(*a*) Wind and weather forecasts and storm warnings for California coast south of San Francisco; advices concerning storm warnings issued for California coast.	(*a*) 11:30 a. m. and 11:30 p. m.	Los Angeles, Calif.
			(*b*) 8 a. m. and 8 p. m. barometric pressure, wind direction and velocity, and state of weather at San Pedro (a. m. only), San Francisco, and San Diego.	(*b*) 11:30 a. m. and 11:30 p. m., respectively.	
			(*c*) Storm warnings issued in afternoon or evening.	(*c*) 5 p. m. and 11:30 p. m.	
Dutch Harbor, Alaska.	2,250	NPR	(*b*) Current barometric pressure, wind direction and velocity, and state of weather.	(*b*) 8:30 a. m. and 8:30 p. m. (135th meridian).	Dutch Harbor, Alaska (naval radio).
Honolulu, T. H.....	2,250	NPM	(*a*) Forecasts of wind and weather for Hawaiian Islands and neighboring ocean areas.	(*a*) 1:30 p. m. (8 a. m.‖).	Honolulu, T. H.
			(*b*) Barometric pressure, wind direction and force, and state of weather at Honolulu.	(*a*) (*b*) 5:30 p. m. (noon‖). (*b*) 1:30 a. m. (8:00 p. m.‖).	
				‖ Honolulu local time.	



This map shows conditions that obtained in the a. m. of January 5, 1922, and is made up of data distributed by radio. Three elements are shown (in red) for each station and ship: Barometric pressure in inches, indicated by figures; wind direction, shown by arrow which flies with the wind; and wind force (Beaufort scale), indicated by the number of feathers on the arrow. The red lines are isobars that pass through points having equal barometric pressure, and were drawn from inspection after the pressure values were entered. The centers of areas of low pressure are indicated by the word LOW and centers of high pressure by the word HIGH.

In the Northern Hemisphere winds blow spirally inward, counter-clockwise, toward and around the center of a LOW, while from the center of a HIGH they blow spirally outward in a direction similar to that described by the hands of a clock. The steeper the pressure gradient (that is, the closer the isobars are together) the higher are the wind velocities.

Copies of this base chart (size 11½ by 14 inches) will be supplied free to vessel masters who regularly take and forward weather observations to the U. S. Weather Bureau, or to the Hydrographic Office, U. S. Navy: others may obtain them at a cost of 75 cents a hundred.

Chart I. Hydrographs of Several Principal Rivers, December, 1921.

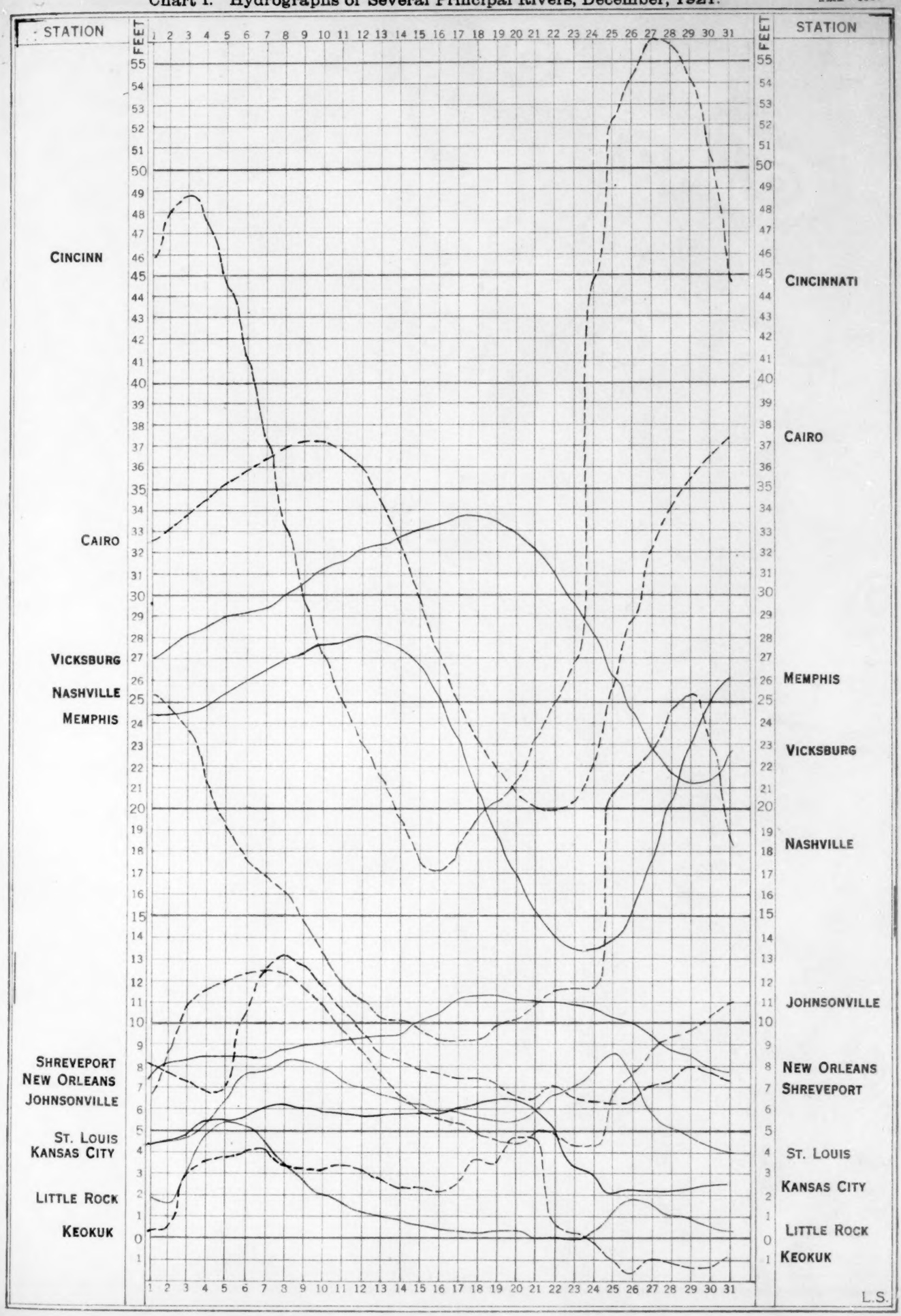

STATION
FEET
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 1
CINCINN
CAIRO
VICKSBURG
NASHVILLE
MEMPHIS
SHREVEPORT
NEW ORLEANS
JOHNSONVILLE
ST. LOUIS
KANSAS CITY
LITTLE ROCK
KEOKUK
CINCINNATI
CAIRO
MEMPHIS
VICKSBURG
NASHVILLE
JOHNSONVILLE
NEW ORLEANS
SHREVEPORT
ST. LOUIS
KANSAS CITY
LITTLE ROCK
KEOKUK
L.S.

Chart II. Tracks of Centers of High Areas, December, 1921.

(Plotted by Wilfred P. Day.)

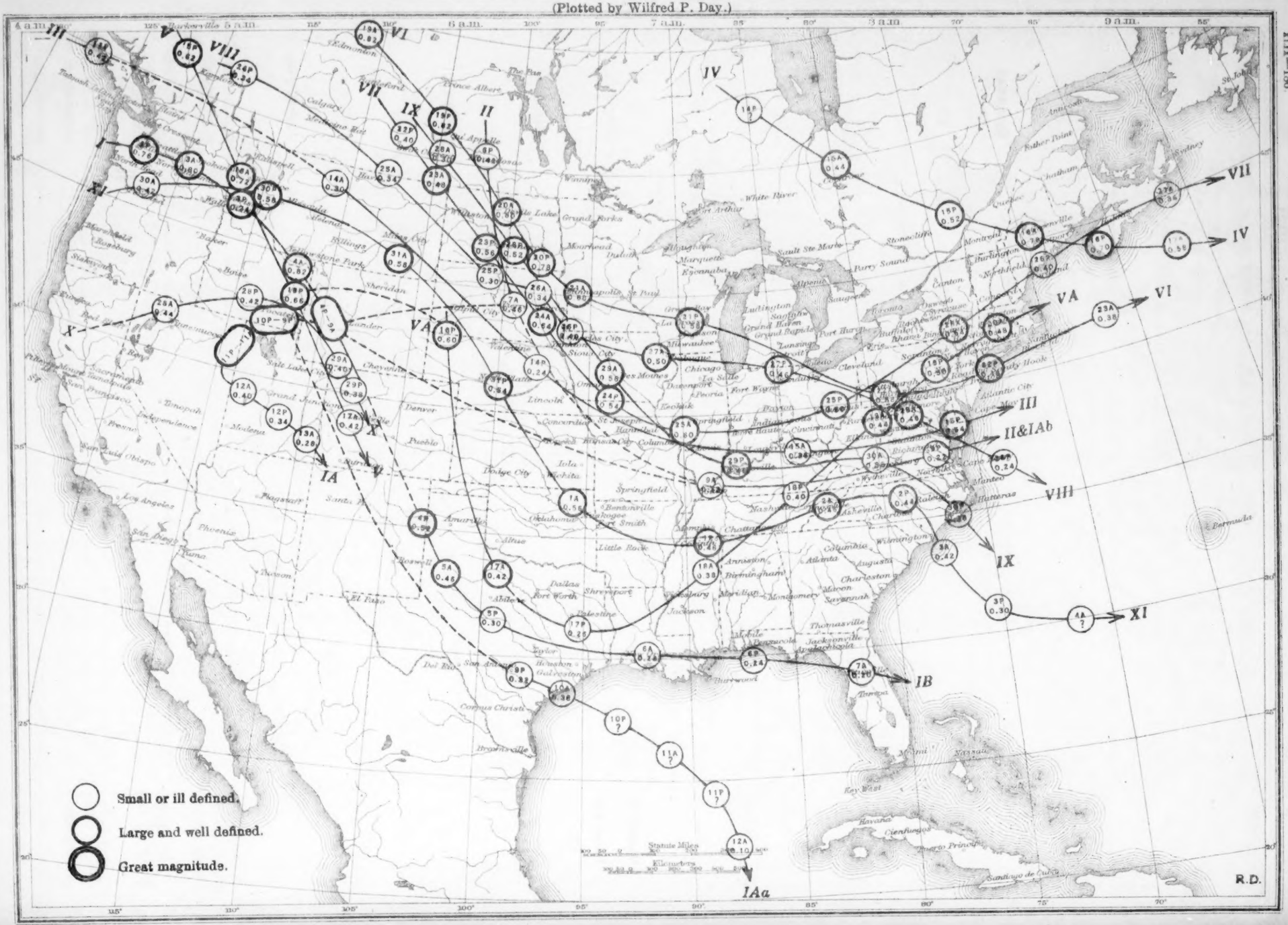


Chart III. Tracks of Centers of Low Areas, December, 1921.

(Plotted by Wilfred P. Day.)

Chart III. Tracks of Centers of Low Areas, December, 1921.

(Plotted by Wilfred P. Day.)

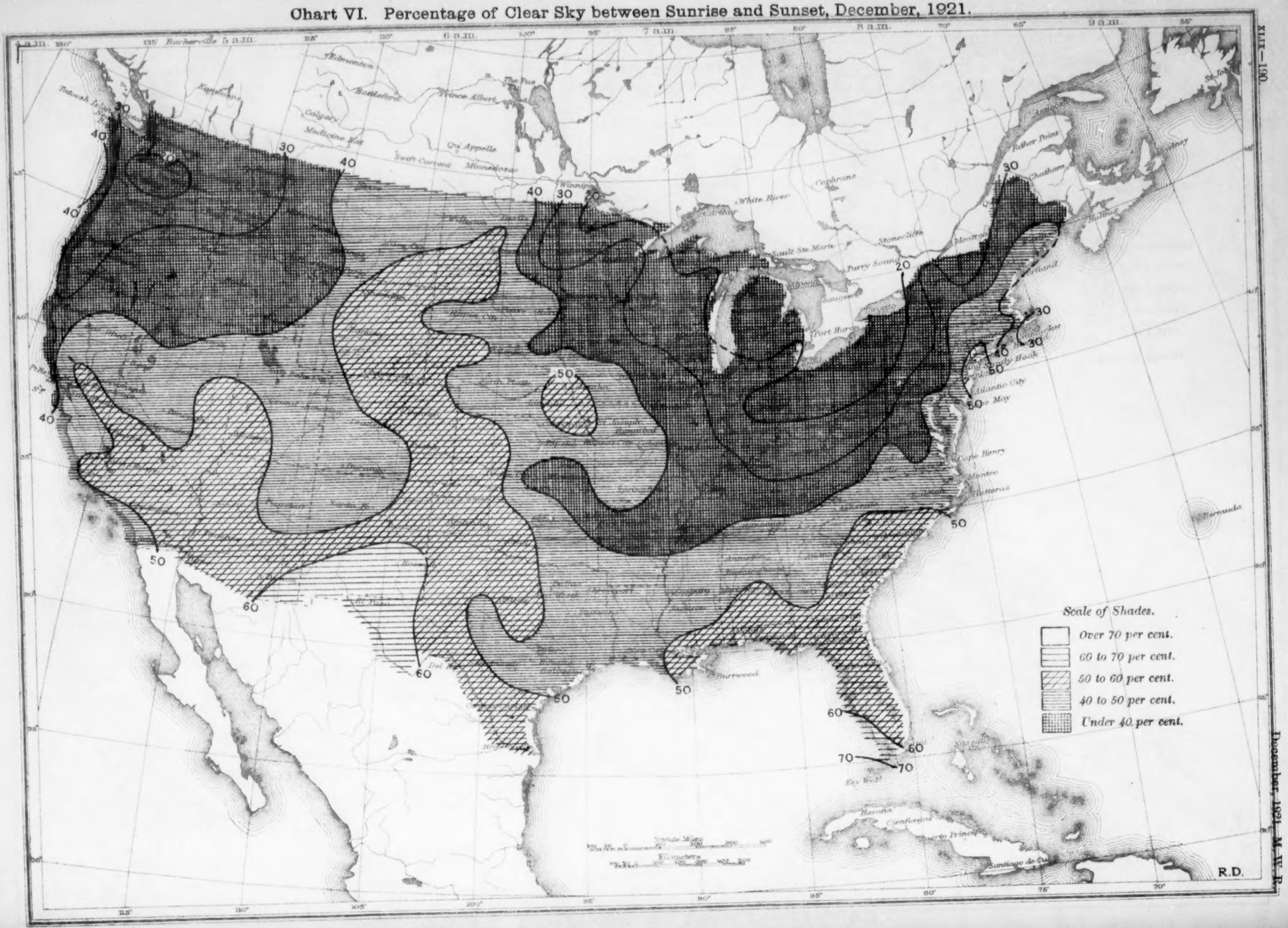
Chart IV. Departure (°F.) of the Mean Temperature from the Normal, December, 1921.

Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart V. Total Precipitation, Inches, December, 1921.

Chart V. Total Precipitation, Inches, December, 1921.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, December, 1921.



M.W.R. December, 1921.—XLIX—190.

Chart VII. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, December, 1921.

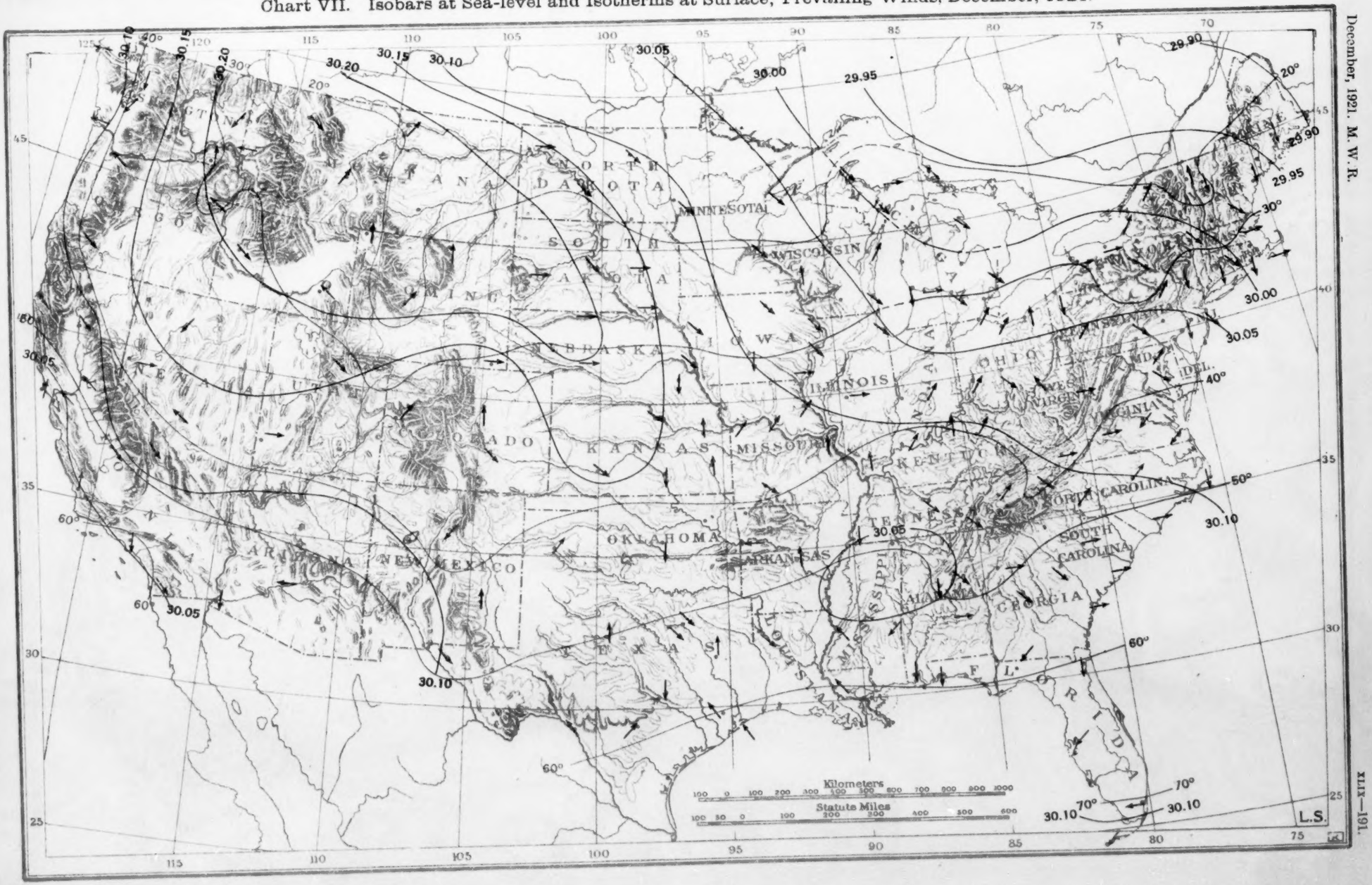


Chart VIII. Total Snowfall, Inches, December, 1921.

Chart IX. Weather Map of North Atlantic Ocean, December 9, 1921.

(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, December 9, 1921.

(Plotted by F. A. Young.)

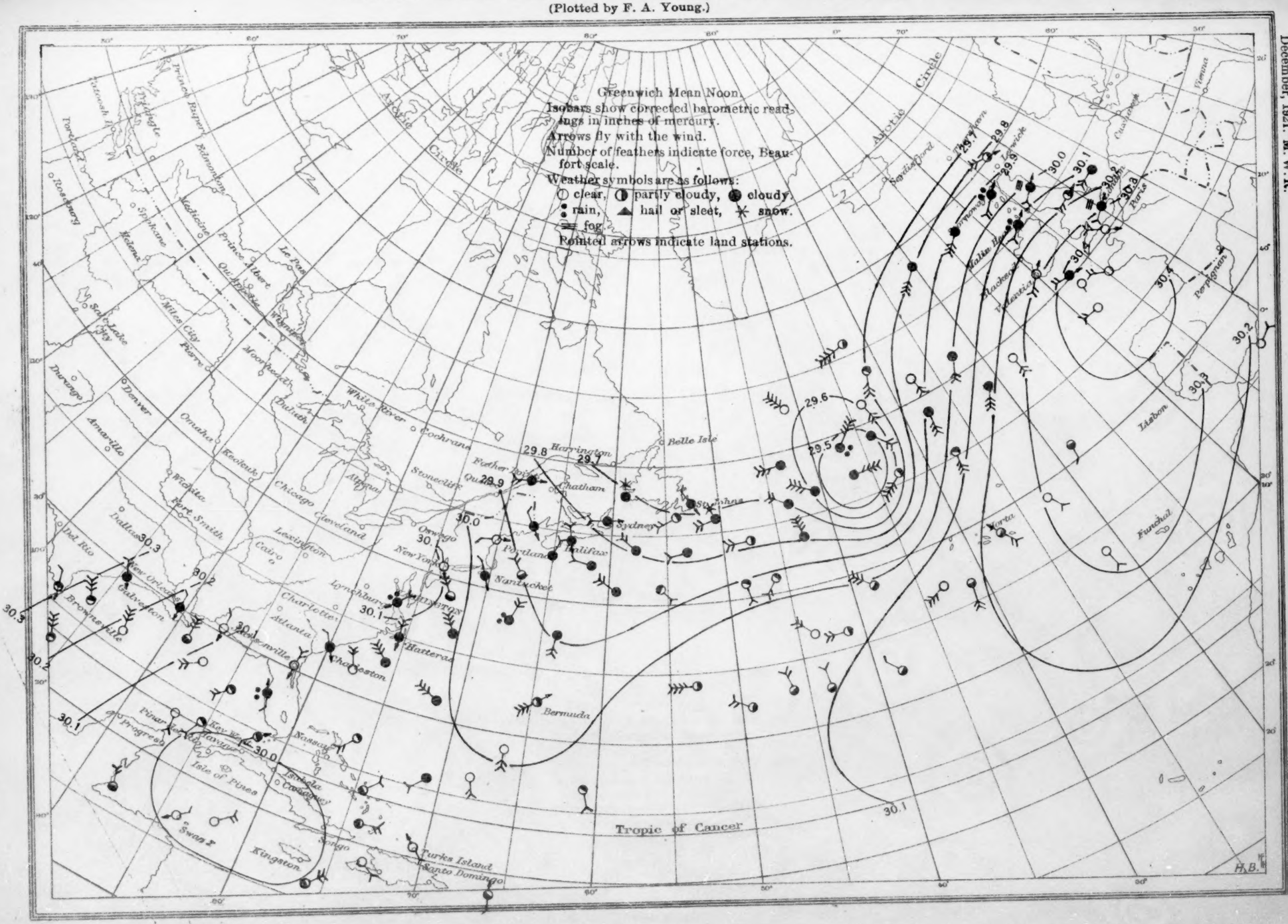


Chart X. Weather Map of North Atlantic Ocean, December 10, 1921.

(Plotted by F. A. Young.)

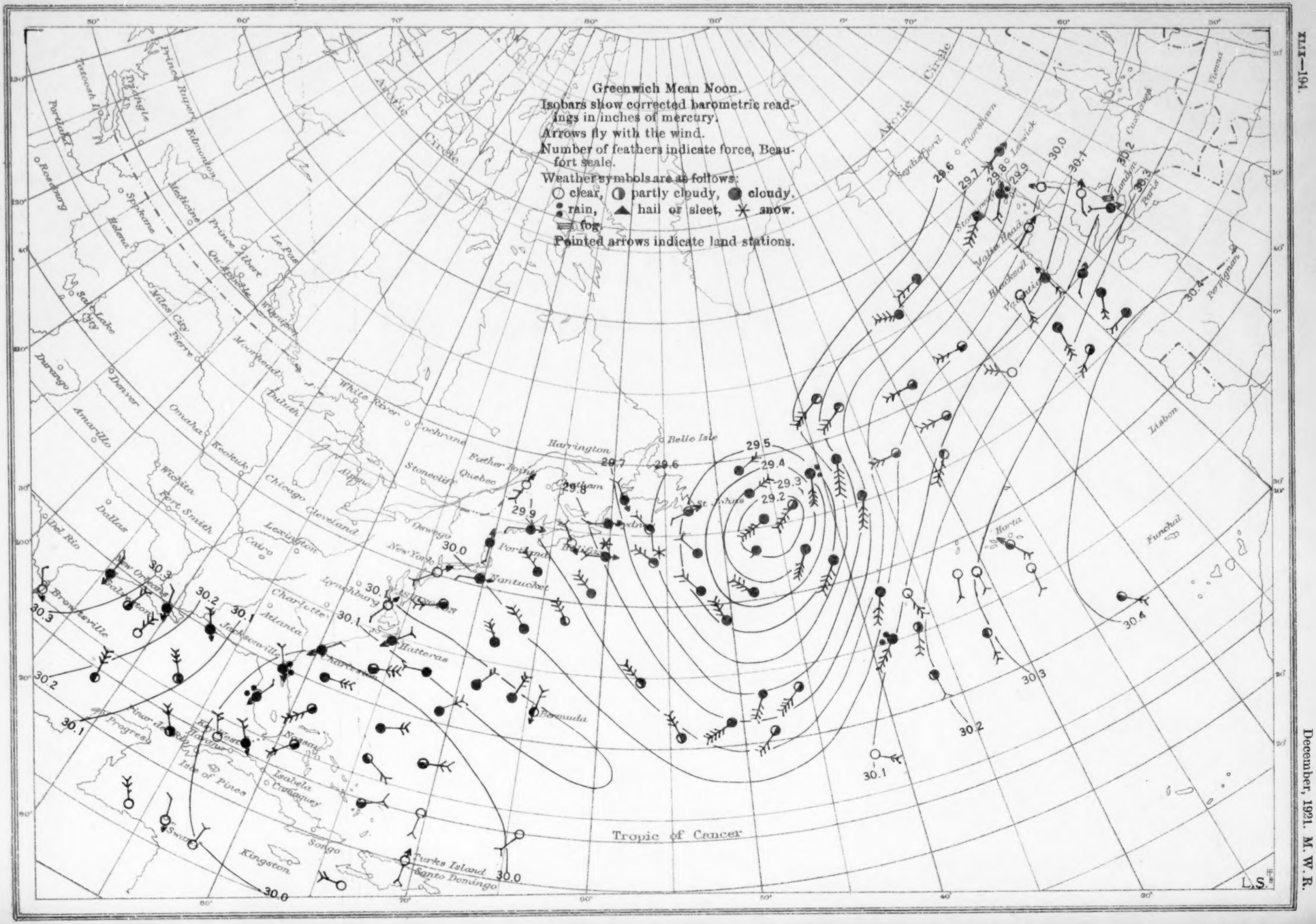


Chart XI. Weather Map of North Atlantic Ocean, December 11, 1921.

(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, December 11, 1921.

(Plotted by F. A. Young.)

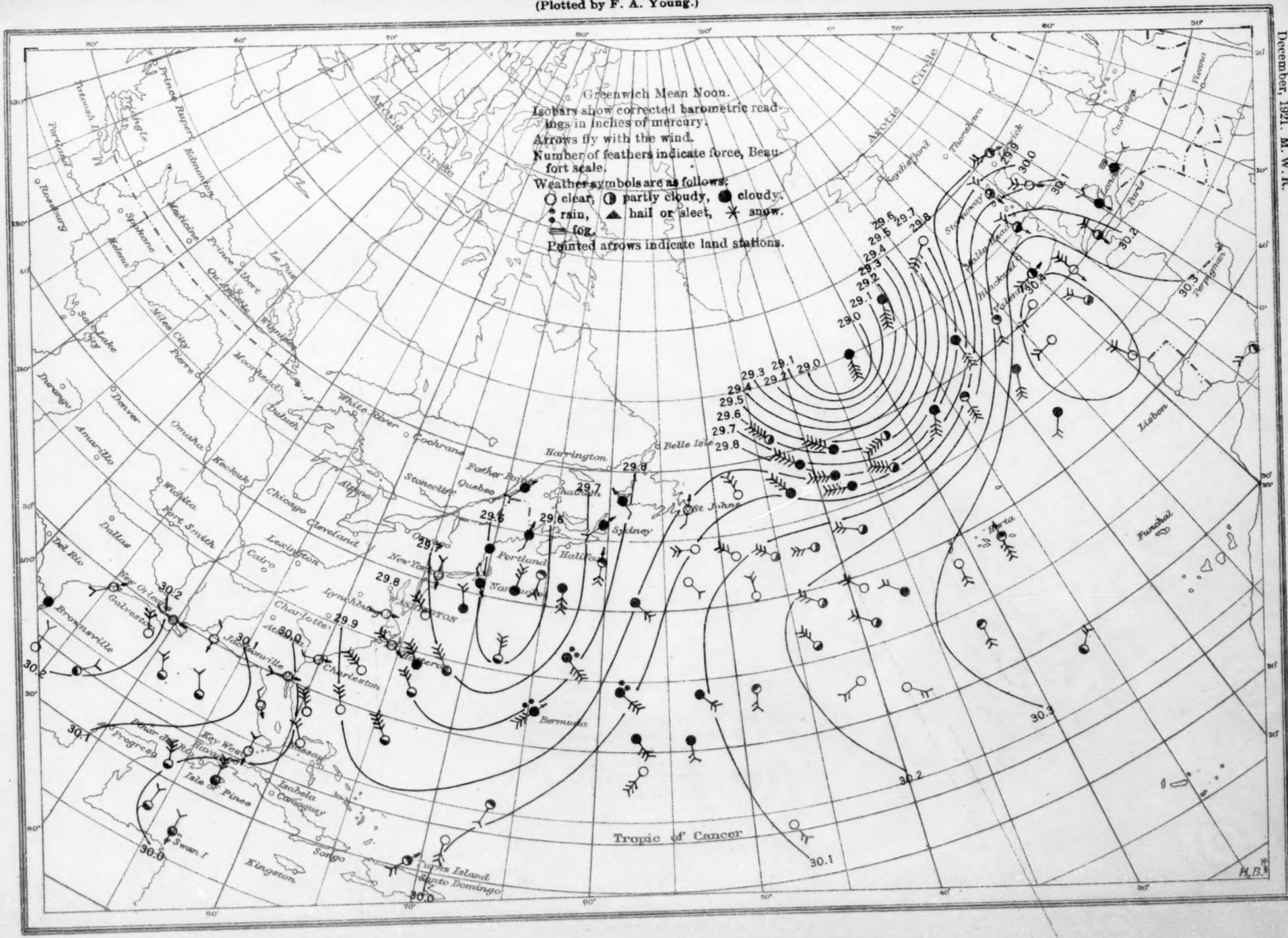


Chart XII. Weather Map of North Atlantic Ocean, December 12, 1921.

(Plotted by F. A. Young.)

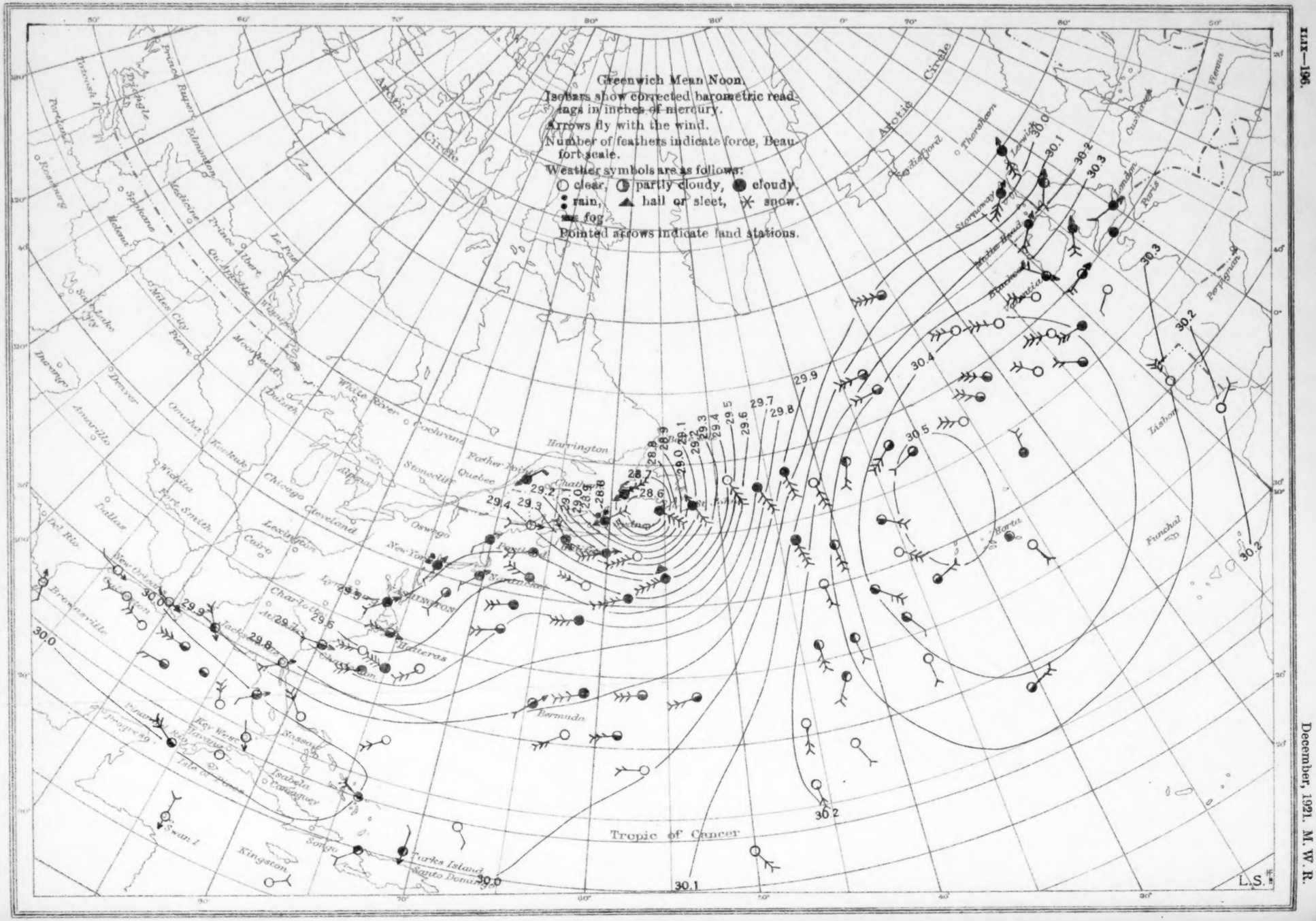

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow.
fog.
Pointed arrows indicate land stations.
Arctic Circle
Tropic of Cancer
L.S.

Chart XIII. Earthquakes in the United States during 1921.

(Plotted by E. W. Woolard.)

Chart XIII. Earthquakes in the United States during 1921.

(Plotted by E. W. Woolard.)

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